Fraunhofer ISIT

Institute for Silicon Technology

Electronic Energy Systems research group

Bachelor's and Master's Thesis Catalogue

Supervisor:
Prof. Dr.-Ing. Marco Liserre

April 2022

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

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

25 – anniversary

www.isit.fraunhofer.de/ees

www.pe.tf.uni-kiel.de

Topics:

- Power Devices and Gate Drivers
- DC-DC Converters
- Batteries
- Reliability in Power Electronics
- Multilevel Converters
- Control of Power Converters and Electric Drives
- Hybrid Grids

Power Devices and Gate Drivers

Fraunhofer ISIT

MSc. Thesis:

Analysis and Design of a Protection Scheme for GaN HEMT in DC/DC Converters

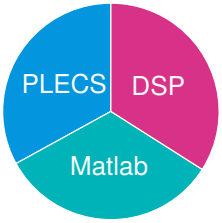
PE 25th anniversary

Requirements

Language
English

Theory
Power Converters ★★★★☆
Electronics ★★★☆☆
Power semiconductors ★★★☆☆
DSP ★★☆☆☆

IT-Skills



Contact

Thiago Pereira
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Supervisor:
Prof. Marco Liserre

Project

DFG GaNius

April 27, 2022

Abstract

Given that the most of short-circuits are not self extinguishing, the protection must be able to clear (at device level) the short-circuit currents in the case of internal failures and to isolate the system after the short-circuit (at system level). Thereby, a high-speed protection scheme is evaluated to handle a short-circuit in GaN HEMT for dc-dc converter applications (e.g. DAB, TAB, and QAB)..

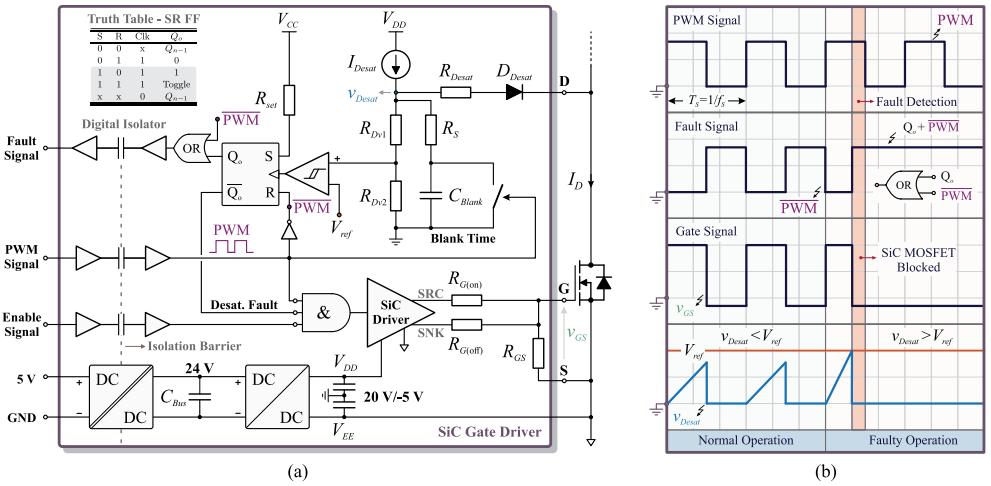


Figure 1: (a) Desaturation method employed to detect the fault on the power device and (c) main waveforms of the gate driver showing that the fault is identified when $v_{Desat} > V_{ref}$ and instantly the device is blocked.

Background

Among the possible internal faults, the semiconductors are the main failure source of the power converter, which can be caused by controller error or saturation; device breakdown (overvoltage), or unexpected behavior of the load (overload or short-circuit). Hence, the semiconductors might assume two possible states: open circuit or short-circuit. For this purpose, a protection scheme should be implemented. The main idea of this topic is to develop a high-speed protection scheme to handle a short-circuit in GaN HEMT for dc-dc converter applications (DAB, TAB, and QAB)

Objectives

Under a short circuit, the device junction temperature can certainly overtake the maximum limit and lead to an irreversible injury. Moreover, the parasitic effects are enhanced with the high di/dt, which can cause ringings and overvoltage. Therefore, a protection scheme should be developed. Moreover, the student will have to assembly and debug the prototype for further validation. Finally, there are some specifics objectives, as follow:

- Review of Literature and Previous Work;
- Prepare a simulation in LTSpice considering different strategies;
- Develop a design guideline for the protection scheme;
- Implement and test the strategies in the lab.

Fraunhofer ISIT

BSc. Thesis:

Design of an S-parameter measurement setup

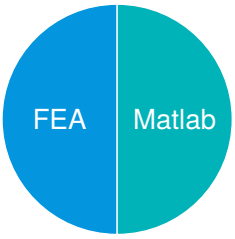
for power electronics system

Requirements

Language
English

Theory
Power Converters ★★★★☆
Signal electronics ★★★☆☆
Wave theory ★★★☆☆
Component reliability ★★☆☆☆

IT-Skills



Contact

Dr.-Ing Yoann Pascal
Dr.-Ing Frank Daschner

Supervisor:
Prof. Marco Liserre

Project

ISIT@CAU

April 25, 2022

Abstract

This thesis will aim at developing an experimental set-up able to conduct S-parameters measurements in the range 10 MHz – 1 GHz on a power module in operation. The set-up will interface the power module under test and the analyser used to perform the measurements (VNA). The challenges associt ated with this research work are dual. First, power modules are not designed for RF measurements, which results in impedance mismatch and connection repeatability issues which will need to be adressed. Second, the association of switching power electronics (with voltage in the range of 400 – 1000 V and currents up to hundreds of amperes) and the analyser (using small signals in the range of few tens of mV and mA) will lead to noise issues, as well as safety concerns (how to protect the analyser, in particular in case of fault of the power electronics?).

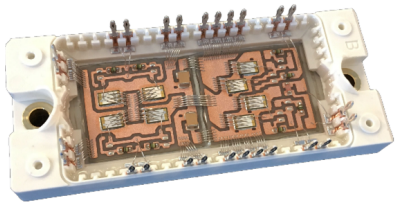


Figure 1: Picture of a typical power module

Background

In a power converter, variations of the processed power, as well as changes in the ambient temperature, induce temperature changes in the components. However, thermal cycling has been identified as the main cause for ageing in power electronic systems, and in particular of degradation of the power modules, which contain the active power devices [1]. Monitoring the state of health (SoH) of the system enable active maintenance strategies to increase lifetime and helps optimally plan maintenance to reduce repair- and downtime- costs [2]. Although various ageing precursors, such as the on-state voltage drop across power devices, have been considered, the high-frequency response has been little investigated [3,4]. However, damages resulting from thermal cycling include bond-wire lift-off and solder degradation, which translate into deviations in component geometries, and therefore in variations of electrical parameters: inductances, resistances, and capacitances [5]. Furthermore, temperature variations result in dilatations that affect the geometry, and therefore the S-parameters of the power module.

Objectives

- Design and prototyping of the experimental set-up
- Simulation-based analysis of the circuit operation
- Experimental validation

Fraunhofer ISIT

MSc. Thesis:

Active Gate Driver for Inverter switching in eMobility applications

Project : PE-Region Platform - Interreg

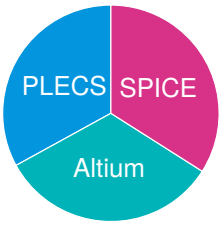
Requirements

Language
English/German

Theory
Power Electronics ★★★★☆
Electric Drives ★★★☆☆

Lab Work
Altium ★★★☆☆
Experiments ★★★☆☆

IT-Skills



Contact

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Project

PE-Region Platform - Interreg

April 25, 2022

Abstract

There are multiple challenges to match the existing Si technology when it comes to cost and realiability simultaneously with SiC/GaN technology. Active gate drivers can improve the reliability and improve utlization of the power switch to reduce the cost. The focus of this thesis is to investigate different active gate driving technologies and find an optimized active gate driver strategy, followed by design and implementation of the hardware to prove the selected methodology.

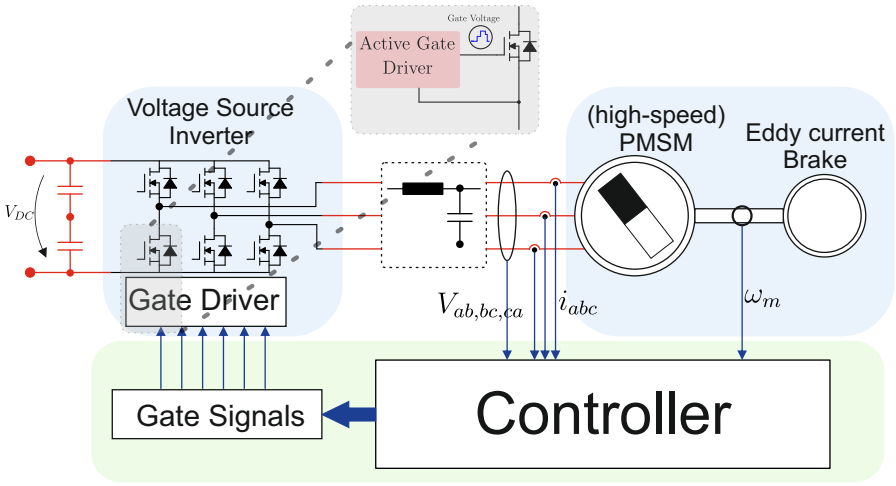


Figure 1: System level view of electric drive system with active gate driver concept

Background

As e-mobility becomes more mainstream, there will be challenges to reduce cost and improve reliability of the electric drive train in these applications. This leads to use of high speed and high frequency motor and inverter to reduce the volume and cost of the system. Due to the current theoretical limitations already reached by use of Si technology, new WBG technology such as Sic/GaN based power switch-based inverters are being researched. Due to fast switching action of these devices, new challenges arise in the field of reliability of which motor winding insulation degrades or partial discharges could occur. Slowing down the switching will result in higher switching losses and lower utilization of the power semiconductor. Active gate drivers overcome these challenges with improved switching performance of power semiconductor.

Objectives

- Trade-off different active gate driver strategies
- Reduce the switching losses and switching slew rate of the power switch
- Experimental validation of the strategy

Fraunhofer ISIT

MSc. Thesis:

Quasi-multilayer GaN-based power modules

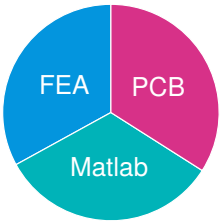
for high-current applications and active reliability-oriented control

Requirements

Language
English

Theory
Power Converters ★★★★☆
PCB design ★★★☆☆
Packaging ★★☆☆☆

IT-Skills



Contact

Dr.-Ing Yoann Pascal
Dr.-Ing Frank Daschner

Supervisor:
Prof. Marco Liserre

Project

ISIT@CAU

April 25, 2022

Abstract

This thesis will target the development, simulation, and characterisation of a high current GaN PM based on a 'quasi-multilayer' substrate combining the high advantages of PCB (multilayer, low inductances) and the high thermal performances of DBC/AMS [1]. In addition, the developed power module will be designed to implement active thermal control capability, based in previous work from the chair of power electronics of Kiel University [2]. Depending upon the student's interest, the topic can be stirred more in the direction of hardware, or of reliability-driven control. Although the project targets GaN transistors, other another technology might be used for the tests, depending upon dies availability.

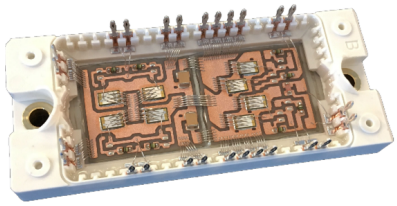


Figure 1: picture of a typical power module, with high parasitic inductances dues to the single layer layout and the use of bonding wires

Background

GaN is gaining high interest in applications for which efficiency, dynamic performances, and power density are key, such as consumer electronics, automotive (including inverter drive and charging stations), and industrial applications. Nevertheless, the high density of GaN transistors requires paralleling several dies to reach high currents. However due to the fast dynamics of these devices, parasitic elements have a great impact on current balancing, leading to unbalanced heating and degraded reliability.

Objectives

- Multi-physical simulation of the target power module
- Design and prototyping of the experimental set-up for experimental characterisation
- Simulation-based study of the impact of the dispersion of the characteristics of the transistors on the dynamic current sharing
- Experimental validation of the simulation results

References:

[1] C. Chen, Y. Chen, Y. Li, Z. Huang, T. Liu and Y. Kang, ”An SiC-Based Half-Bridge Module With an Improved Hybrid Packaging Method for High Power Density Applications,” in IEEE Trans. Ind. Electron., vol. 64, no. 11, 2017, doi: 10.1109/TIE.2017.2723873.
[2] V. Ferreira, M. Andresen, B. Cardoso and M. Liserre, ”Pulse-Shadowing-Based Thermal Balancing in Multichip Modules,” in IEEE Trans. Ind. App., vol. 56, no. 4, 2020, doi: 10.1109/TIA.2020.2993526.

Fraunhofer ISIT

MSc. Thesis:

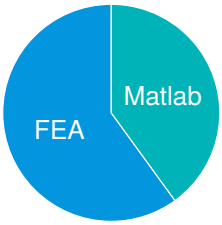
Impedance spectroscopy for condition monitoring of a Power Module used for power electronics conversion

Requirements

Language
English

Theory
Power Converters ★★★★☆
Wave theory ★★★☆☆
Component reliability ★★☆☆☆

IT-Skills



Contact

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ISIT@CAU

April 25, 2022

Abstract

In a power converter, variations of the processed power, as well as changes in the ambiant temperature, induce temperature changes in the components. However, thermal cycling has been identified as the main cause for ageing in power electronic systems, and in particular of degradation of the power modules, which contain the active power devices [1]. Monitoring the state of health (SoH) of the system enable active maintenance strategies to increase lifetime and helps optimally plan maintenance to reduce repair- and downtime- costs [2]. Although various ageing precursors, such as the on-state voltage drop across power devices, have been considered, the high-frequency response has been little investigated [3,4]. However, damages resulting from thermal cycling include bond-wire lift-off and solder degradation, which translate into deviations in component geometries, and therefore in variations of electrical parameters: inductances, resistances, and capacitances. Furthermore, temperature variations result in dilatations that affect the geometry, and therefore the S-parameters of the power module [5]. This thesis will therefore investigate how measuring the S-parameters of a power module can help estimate its state of health.

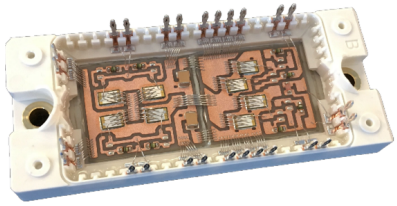


Figure 1: Picture of a typical power module

Objectives

- Modeling (CST-Microwave Studio) of a power module
- Simulation of the effect of ageing and temperature on its S-parameters
- Experimental validation of the simulations results
- Design of an improved test set-up to maximise measurement sensitivity and repeatability

References:

[1] J. Falck, C. Felgemacher, A. Rojko, M. Liserre, and P. Zacharias, “Reliability of Power Electronic Systems: An Industry Perspective,” IEEE Ind. Electron. Mag., 12(2)

[2] V. Raveendran, M. Andresen and M. Liserre, ”Lifetime Control of Modular Smart Transformers Considering the Maintenance Schedule,” 2018 IEEE Energy Conversion Cong. and Expo. (ECCE), 2018

[3] A. Hanif, D. DeVoto and F. Khan, ”Bond Wire Damage Detection and SOH Estimation of a Dual-Pack IGBT Power Module Using Active Power Cycling and Reflectometry”, in IEEE Trans. Power Electron., 35(7), 2020.

[4] B. Zheng, C. Hunat, W. Yuan, N. Suthiwongsunthorn and S. Chungpaiboonpatana, ”Failure isolation for advanced packages using time-domain reflectometry ”, 2011 IEEE 13th Electronics Packaging Technology Conf. 201

[5] Y. Pascal, F. Daschner, M. Liserre, M. Höft, “Condition monitoring of power module using S-Parameters, TDR, and TDT”, submitted to ESREF 2022

Fraunhofer ISIT

BSc. Thesis:

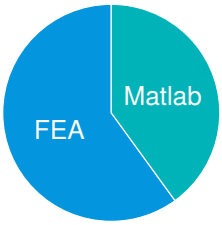
Impedance sprectroscopy for condition monitoring of a Power Module used for power electronics conversion

Requirements

Language
English

Theory
Power Converters ★★★★☆
Wave theory ★★★☆☆
Component reliability ★★☆☆☆

IT-Skills



Contact

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

Project

ISIT@CAU

April 25, 2022

Abstract

In a power converter, variations of the processed power, as well as changes in the ambiant temperature, induce temperature changes in the components. However, thermal cycling has been identified as the main cause for ageing in power electronic systems, and in particular of degradation of the power modules, which contain the active power devices [1]. Monitoring the state of health (SoH) of the system enable active maintenance strategies to increase lifetime and helps optimaly plan maintenance to reduce repair- and downtime- costs [2]. Although various ageing precursors, such as the on-state voltage drop across power devices, have been considered, the high-frequency response has been little investigated [3,4]. However, damages resulting from thermal cycling include bond-wire lift-off and solder degradation, which translate into deviations in component geometries, and therefore in variations of electrical parameters: inductances, resistances, and capacitances. Furthermore, temperature variations result in dilatations that affect the geometry, and therefore the S-parameters of the power module. This thesis will therefore investigate how measuring the S-parameters of a power module can help estimate its state of health.

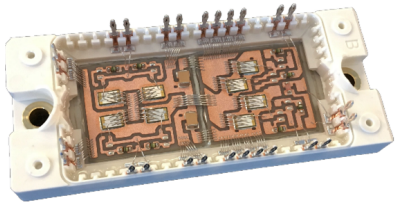

Figure 1: Picture of a typical power module

Objectives

- Modeling (CST-Microwave Studio) of a simple power module
- Simulation of the effect of ageing on the S-parameters
- Experimental validation of the simulations results

References:

[1] J. Falck, C. Felgemacher, A. Rojko, M. Liserre, and P. Zacharias, “Reliability of Power Electronic Systems: An Industry Perspective,” IEEE Ind. Electron. Mag., 12(2) K. Ma, M. Liserre, F. Blaabjerg, T. Kerekes, ”Thermal Loading and Lifetime Estimation for Power Device Considering Mission Profiles in Wind Power Converter”, IEEE Trans. Power Electron., 2015

[2] V. Raveendran, M. Andresen and M. Liserre, ”Lifetime Control of Modular Smart Transformers Considering the Maintenance Schedule,” 2018 IEEE Energy Conversion Cong. and Expo. (ECCE), 2018

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Fraunhofer ISIT

MSc. Thesis:

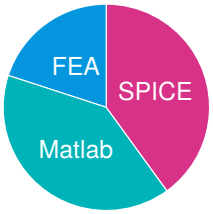
Design and test of an experimental set-up for online S-parameter measurement of a power electronics module

Requirements

Language
English

Theory
Power Converters ★★★★☆
Signal electronics ★★★☆☆
Wave theory ★★★☆☆
Component reliability ★★☆☆☆

IT-Skills



Contact

Dr.-Ing Yoann Pascal
Dr.-Ing Frank Daschner

Supervisor:
Prof. Marco Liserre

Project

ISIT@CAU

April 25, 2022

Abstract

This thesis will aim at developing an experimental set-up able to conduct S-parameters measurements in the range 10 MHz – 1 GHz on a power module in operation. The set-up will interface the power module under test and the analyser used to perform the measurements (VNA). The challenges associtated with this research work are dual. First, power modules are not designed for RF measurements, which results in impedance mismatch and connection repeatability issues which will need to be adressed. Second, the association of switching power electronics (with voltage in the range of 400 – 1000 V and currents up to hundreds of amperes) and the analyser (using small signals in the range of few tens of mV and mA) will lead to noise issues, as well as safety concerns (how to protect the analyser, in particular in case of fault of the power electronics?).

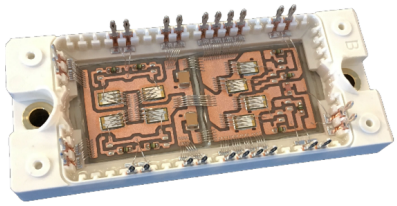


Figure 1: Picture of a typical power module

Background

In a power converter, variations of the processed power, as well as changes in the ambient temperature, induce temperature changes in the components. However, thermal cycling has been identified as the main cause for ageing in power electronic systems, and in particular of degradation of the power modules, which contain the active power devices [1]. Monitoring the state of health (SoH) of the system enable active maintenance strategies to increase lifetime and helps optimally plan maintenance to reduce repair- and downtime- costs [2]. Although various ageing precursors, such as the on-state voltage drop across power devices, have been considered, the high-frequency response has been little investigated [3,4]. However, damages resulting from thermal cycling include bond-wire lift-off and solder degradation, which translate into deviations in component geometries, and therefore in variations of electrical parameters: inductances, resistances, and capacitances. Furthermore, temperature variations result in dilatations that affect the geometry, and therefore the S-parameters of the power module.

Objectives

- Modeling (CST-Microwave Studio or Ansys Maxwell/Q3D) of a simple target power module
- Design and prototyping of the experimental set-up

- Simulation-based analysis of the operation in nominal operation, and under fault
- Experimental validation of the simulation results

References:

[1] J. Falck, C. Felgemacher, A. Rojko, M. Liserre, and P. Zacharias, “Reliability of Power Electronic Systems: An Industry Perspective,” IEEE Ind. Electron. Mag., 12(2), 2018 K. Ma, M. Liserre, F. Blaabjerg, T. Kerekes, ”Thermal Loading and Lifetime Estimation for Power Device Considering Mission Profiles in Wind Power Converter”, IEEE Trans. Power Electron., 2015

[2] V. Raveendran, M. Andresen and M. Liserre, ”Lifetime Control of Modular Smart Transformers Considering the Maintenance Schedule,” 2018 IEEE Energy Conversion Cong. and Expo. (ECCE), 2018

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Batteries

Fraunhofer ISIT

BSc. Thesis:
Temperature-Aware Li-Ion Batteries SOC Estimation

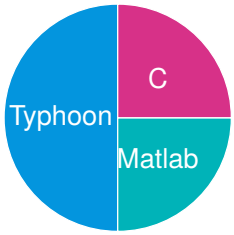
Batteries: Battery Pack for E-Mobility

Requirements

Language
English

Theory
Lithium-Ion Batteries ★★★★☆
SOC Estimation ★★★★☆
Thermal Design ★★☆☆☆
Kalman Filter ★★☆☆☆

IT-Skills



Contact

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Supervisor:
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Project

BAEW: Laboratory for Reliable Battery-Assisted Energy Conversion

April 18, 2022

Abstract

State-of-Charge (SOC) of batteries is the core of any battery management system (BMS) which serves as the engine of cell balancing in battery modules and/or packs. High-speed and accurate SOC estimation is essential for low-cost implementation of BMSs. However, thermal issues which appear in real-world use of batteries impact degrades the SOC estimation. You may develop mathematical methods for improving the SOC estimation in filter-based methods such as Kalman filter family to compensate for thermal issues.

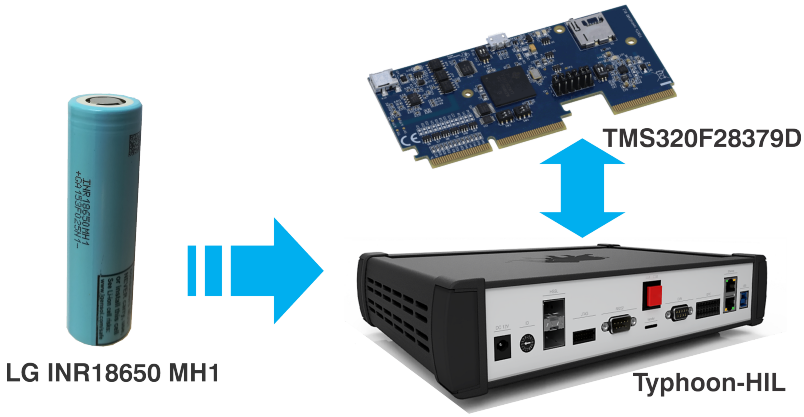


Figure 1: Hardware setup for lithium-ion battery SOC estimation

Background

Lithium ion (Li-ion) batteries are the dominant battery technology in electric vehicle (EV) industry. Even though li-ion battery technology is sufficiently developed, however, its optimal utilization depends on many factors such as BMS and environmental conditions and in particular thermal design. Safely and optimal utilization of the battery capacities depends on the BMS. This thesis aims to develop new open circuit voltage (OCV) estimation techniques based on mathematical algorithms to improve the performance of conventional Kalman Filter based SOC estimation methods under various temperature conditions. **I would suggest the topic to bachelor students who wants to understand lithium ion batteries and follow their carrier in battery sector.**

Objectives

- Literature review of SOC estimation methods
- Study the impact of temperature on SOC estimation
- Develop a Kalman filter with a new OCV estimation algorithm
- Implement and evaluate the method in the Typhoon HIL

Fraunhofer ISIT

BSc. Thesis:

AC content charging and discharging of LiS Cells

LiS: Lithium Sulfur Battery

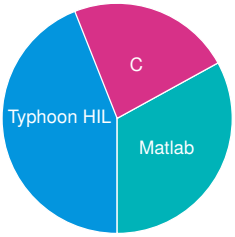
Requirements

Language
Deutsch/English

Theory
DC/DC Converters ★★★☆☆
System Theory ★★★☆☆
Batteries ★★★★☆
Material Science ★★★☆☆

Lab Work
Electronics ★★★☆☆

IT-Skills



Contact

Max Placzek
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Supervisor:
Prof. Marco Liserre

Project

BAEW: Laboratory for Reliable Battery-Assisted Energy Conversion

April 26, 2022

Abstract

Batteries are rarely charged and discharged by a true DC current. From line and power converter ripple to variable demand of loads, AC components are almost always present in the waveform. Despite constituting no net charge transfer, AC components have the capability of interacting and modulating electrochemical processes and additional, engineered AC content has been proposed for this purpose. This thesis aims to further investigate these effects on both the charging and discharging process of experimental lithium batteries as manufactured by the Chair of Functional Nanomaterials.

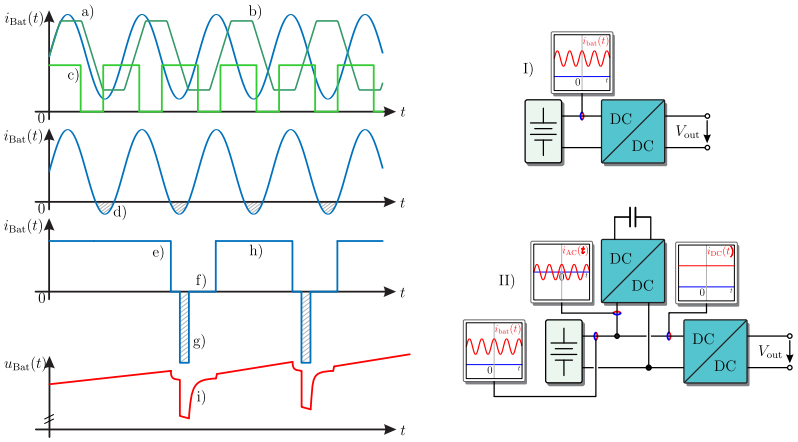


Figure 1: Idealized battery currents a)-g) that can occur as side effects (I) or engineering choice (II) and a voltage response (i) to the currents of (e)-(h) showing various time constants of the electrochemistry.

Background

Electrochemical processes are not instantaneous, but subject to various delays due to diffusion and reaction rates. AC currents superimposed on the DC charging/discharging process can exert significant influence on electrochemical processes by modulating the chemical reactions i.e. by giving time for diffusion processes during periods of reduced current. Ongoing research shows that the cycle life of LiS cells can be significantly improved by pulse charging. It remains as a scientific task to identify the range of parameters suitable for this purpose and to identify weather similar effects exist for the discharge process.

Objectives

- Implement and compare charging and discharging processes with AC content for LiS cells in Typhoon HIL
- Identify optimum charging parameters

Fraunhofer ISIT

BSc. Thesis:

Thermal Characterization of LiS Cells

LiS: Lithium Sulfur Battery

PE 25th anniversary

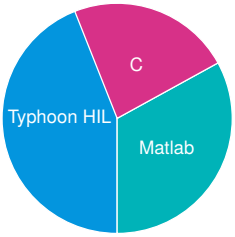
Requirements

Language
Deutsch/English

Theory
DC/DC Converters ★★★☆☆
System Theory ★★★☆☆
Batteries ★★★★★
Material Science ★★★☆☆

Lab Work
Electronics ★★★☆☆

IT-Skills



Contact

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Supervisor:
Prof. Marco Liserre

Project

BAEW: Laboratory for Reliable Battery-Assisted Energy Conversion

April 26, 2022

Abstract

Batteries are frequently charged and discharged at widely varying temperatures. Temperature has a major impact on electrochemical processes and alters cycle life and electrical behavior of battery cells. This thesis aims to further investigate the effects on both the charging and discharging process of experimental Lithium Batteries as manufactured by the Chair of Functional Nanomaterials.

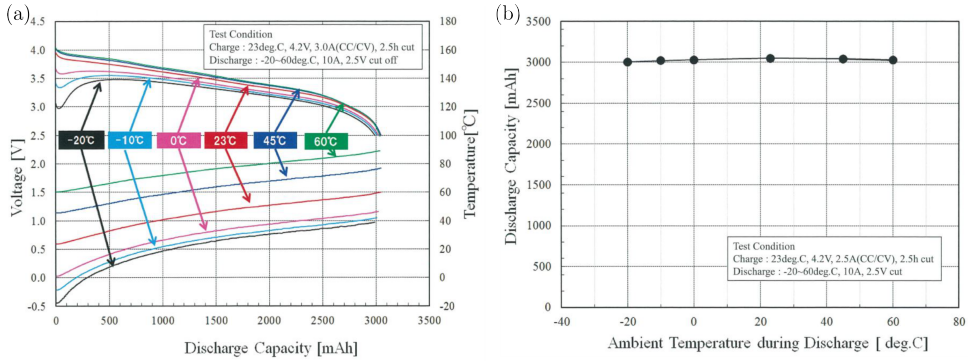


Figure 1: Temperature dependence (a) of the electrical behavior an LNC Li-Ion battery. (b) shows the cumulative result. [Source: Sony, INR18650-35E Datasheet]. The behavior is considerably temperature dependent, while capacity is maintained, efficiency is not maintained at low temperatures due to increased internal voltage drop. Note how self heating due to high rate discharge modulates the behavior. These behaviors shall be documented for new battery chemistries and the knowledge used to improve their operation.

Background

The temperature dependence of chemical processes is frequently summarized by a rule of thumb known as the Arrhenius equation. A temperature change of 10K corresponds to a twofold change in reactivity. Hence, even small temperature changes can have a dramatic impact. Just a few ten degrees of battery temperature above or below room temperature severely alter battery behavior. This Thesis aims to investigate these effects under different electrical operating regimes for Lithium Sulfur Batteries.

Objectives

- Implement charging and discharging processes for LiS cells in Typhoon HIL based battery analysis system
- Test these Regimes in the controlled environment of the BAEW Climate Chamber
- Identify temperature impact on nonlinear battery behavior

Control of Power Converters and Electric Drives

Fraunhofer ISIT

MSc. Thesis:

P-HIL for Evaluation of Battery Lifetime in Vehicles Equipped with Active-Controlled Suspension System

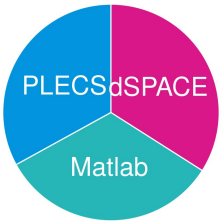
25th anniversary

Requirements

Language
English

Theory
Batteries ★★★★★
Electric Drives ★★★★★
Power Converters ★★★☆☆
Real-time Sim ★★☆☆☆

IT-Skills



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Project

Master Epico

April 25, 2022

Abstract

Ride safety and the handling capabilities of a car are contrasting goals when designing its suspension system. Mechatronic suspensions can ease this conflict by employing controlled force actuators between the wheels and the chassis. The actuators must be supplied, so harvesting and storaging the dissipated energy by the mechanical system becomes essential to achieve high efficiency. Road profile and suspension control tuning can have an impact on the storage system lifetime. Optimization of the actuator control parameters which take in account for both ride safety/handling and battery lifetime is essential in future e-vehicles

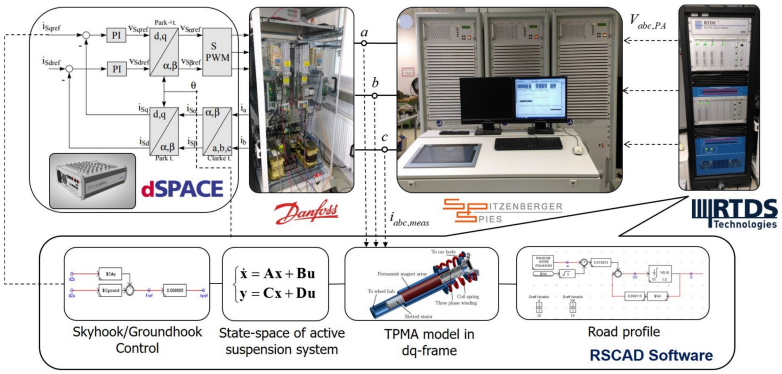


Figure 1: P-HIL active suspension setup

Background

The goal of this work is to investigate the impact of active suspension systems on the lifetime of the e-vehicle battery when driving in different road conditions. The hardware validation would need the realization of a laboratory quarter-car test rig, which is wasteful if the focus is on power electronics. Power hardware in the loop (P-HIL) simulation offers the possibility to connect a real-time simulation of the road profile, of mechanical and electrical components of a car with the hardware under test (HUT) through a power interface. Implementation of a P-HIL test bench with dSPACE real-time simulator is essential requirement for achieving the main goal.

Objectives

- Analysis on the impact of the road profile and suspension tuning on the battery lifetime;
- Implementation of a mechatronic suspension and its control in dSPACE real-time simulator.
- Implementation of a P-HIL test bench for testing the DC/AC power converter and for characterization of the battery lifetime.

DC-DC Converters

Fraunhofer ISIT

Master's Thesis:

High-power multiwinding planar transformer parasitic parameter optimization

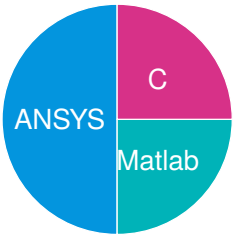
PE 25th anniversary

Requirements

Language
English/German

Theory
Transformer ★★★★☆
Parasitic components ★★★★★
Power converter ★★★☆☆
Multiwinding ★★★★★

IT-Skills



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Project

R+T-Project

April 22, 2022

Abstract

Planar transformers are highly important in high frequency applications, due to the lower and better control of the parasitic components. Multiwinding transformer face the problem that the control of parasitic components is complex, due to coupled magnetic leakage energy. This thesis tries to optimize the parasitic parameters in a multiwinding planar transformer.

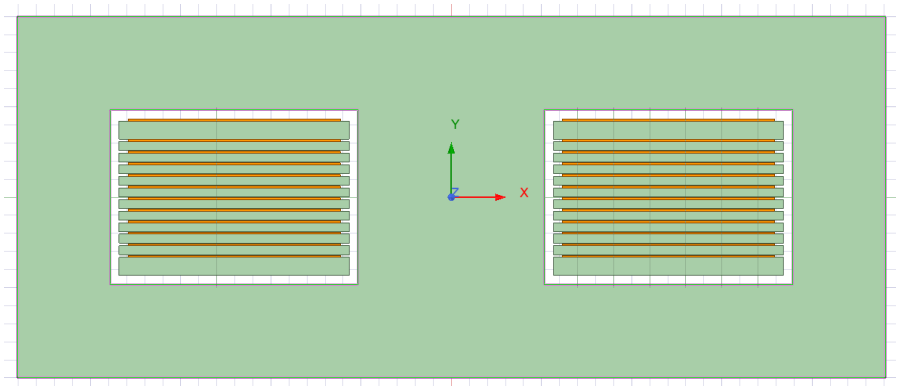


Figure 1: 2D-Model of a planar transformer

Background

Control of parasitic components in transformer is important to decrease the overall losses and to decrease the voltage spikes. The control of parasitic components in multiwinding transformer is more difficult than in non multiwinding transformers. Interleaving the windings in non multiwinding transformers usually lowers the leakage inductance, but this does not apply for multiwinding transformer. Finite element-based design is carried out to find the optimal parameter design with measurements in the lab of parasitic parameters.

Objectives

- Review of parasitic components in transformers
- Analytic approach for parasitic parameter optimization
- FEM design and optimization of multiwinding planar transformer

Fraunhofer ISIT

MSc. Thesis:

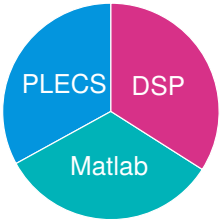
Analysis and Design of a Capacitive-Coupled Three Level DC/DC Converter

Requirements

Language
English

Theory
Power Converters ★★★★☆
Magnetics ★★☆☆☆
Power semiconductors ★★★☆☆
DSP ★★★★☆

IT-Skills



Contact

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Supervisor:
Prof. Marco Liserre

Project

DFG GaNius

April 27, 2022

Abstract

The capacitive coupling behavior, instead of inductive, allows a much higher power density, higher efficiency, and improves repeatability. The idea is the generation three-level dc/dc a capacitive coupled topology. It has the ability to share the voltage among the input devices, allowing the utilization of lower rated components, with usually improved characteristics (c.f. Fig. iii), therefore increasing overall efficiency.As a result the power devices are smaller and available in discrete packages, which leads to the elimination of the transformer and reducing parametric variations. The topic consists of the generation of three-level capacitive-coupled.

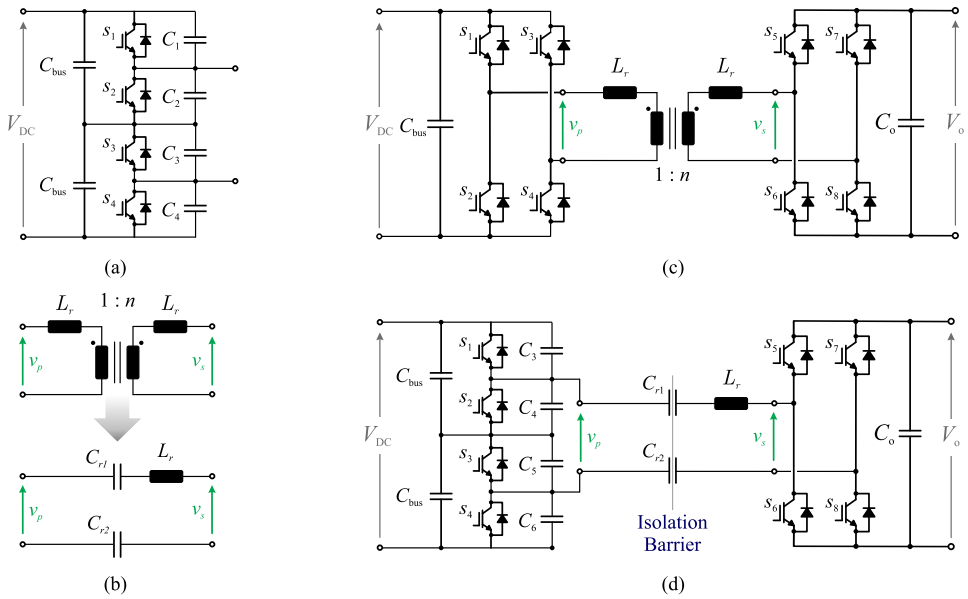


Figure 1: (a) Three level building block; Inductive and capacitive coupling considering external inductances; The proposed topology is a combination of a (c) conventional Two-Level Dual Active Bridge (2L-DAB) and the building blocks (a)-(b), named (c) Capacitive Coupled Three-Level Dual Active Bridge (CPT-3L-DAB). Yet, the concept can be extrapolate for the other converter such as: Serie-Resonant (SR) converter and Phase Shift Full-Bridge (PSFB), yielding CPT-3L-SR and CPT-3L-PSFB, respectively

Background

The proposed topology has the ability to share the voltage among the input devices, allowing the utilization of lower-rated components, with usually improved characteristics. As a result, the topology is able to improve the overall efficiency of the system. Furthermore, with the compilation of these characteristics it is possible to assume one fitting application matches the battery systems with 48 V output voltage and a higher input, in the range of 200 V to 400 V that shares the input voltage among the devices, allowing for the usage of lower-rated components and the elimination of the

transformer, which usually have a better figure of merit $R_{DS,on} \cdot Q_{oss}$. Further, the elimination of the transformer reduces the intrinsic parameters changes of one topology to the other, providing advantages in a production scale.

Objectives

The main objective of the thesis is to analyze, evaluate, and validate the proposed topology in a simulation environment and also by means a hardware prototype available at the Chair. Moreover, the student will have to assembly and debug the prototype for further validation. Moreover, there are some specifics objectives, as follow:

- Review of Literature and Previous Work;
- Define the operation principle using PWM;
- Analyze the classical Isolated DC/DC Converters (resonant and non-resonant topologies);
- Develop a design guideline for the converter;
- Prepare simulations for further validations;
- Implement and test the power converter in the lab.

Hybrid Grids

Fraunhofer ISIT

MSc. Thesis:

Analysis and Control of Full-Bridge Submodule Based MMC with BESS for MVDC Grids

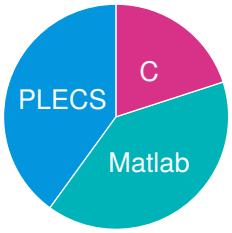
P E 25th anniversary

Requirements

Language
English

Theory
Renewable ★★★☆☆
Power Converter ★★★★☆
Control ★★★★☆
Battery ★★★☆☆

IT-Skills



Contact

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Supervisor:
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Project

ENSURE: Neue EnergieNetzStruktURen für die Energiewende

April 8, 2022

Abstract

In recent several years, battery energy storage systems (BESSs) based on modular multilevel converters (MMCs) have been studied for the MVDC distribution grids in terms of stabilizing the grid as well as storing the remaining energy. This thesis studies on state-of-charge (SoC) balancing method in the BESS with full-bridge (FB) SMs based MMCs, which has an ability to the DC fault current capability.

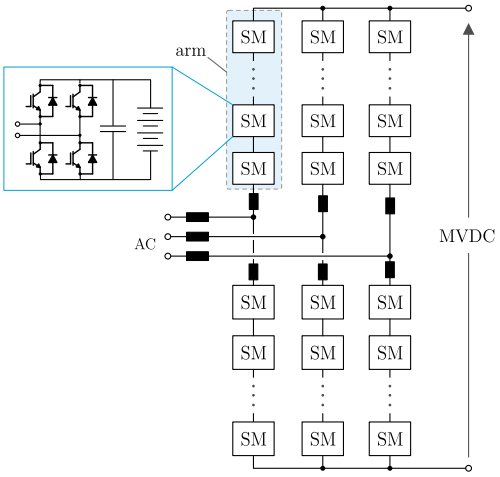


Figure 1: BESS MMC for MVDC Grids

Background

A modular multilevel converter (MMC) is a promising technology for high- and medium-voltage (HV and MV) DC applications. MMCs is a suitable topology to be combined with the BESS for MVDC distribution grids because AC and DC sides of MMC systems can be controlled independently by the decoupled AC/DC models. The FBSM based MMC can output a negative voltage and this characteristic could provide more flexibility in balancing SOC between battery packs in each SM. Therefore, a new control possibility for the SOC balancing management can be studied and discovered considering the characteristics of FBSM MMCs.

Objectives

- Review of Literature and Previous Work
- Analysis of modeling and control methods for BESS MMCs.
- Proposal of a new SoC balancing management between SM battery packs in FBSM based BESS MMC.

Multilevel Converters

Fraunhofer ISIT

M.Sc. Thesis:

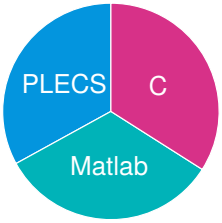
Reliability Evaluation and Fault-Tolerance Strategies for Modular Multilevel Converters

Requirements

Language
English

Theory
Multilevel Converters ★★★★☆
Power Devices ★★★★☆
Control ★★★★☆
Statistics ★★★☆☆

IT-Skills



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Project

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

April 8, 2022

Abstract

Since they were first proposed, modular multilevel converters (MMC) have been strongly studied in the literature. Due to their high component count, some concerns regarding their reliability arise, and several fault-tolerance schemes have been proposed in recent years. Therefore, this thesis studies the suitable MMC solution according to the trade-off between the converter cost and the reliability requirement.

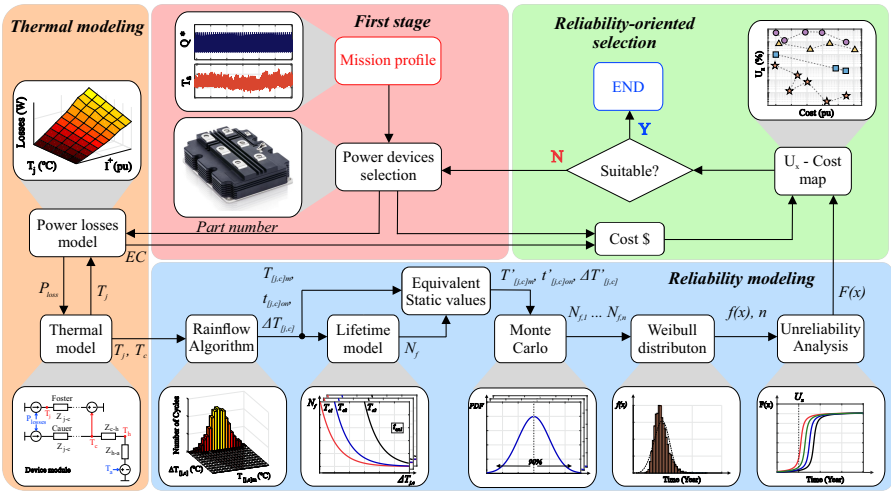


Figure 1: Flowchart for the reliability-oriented design of power devices.

Background

To be able to operate at medium- or high-voltage levels, a higher number of power electronic components is required for MMCs, compromising the converter reliability. In this way, a fault-tolerance method can be added to improve the converter reliability. There is a minimum limit of redundant submodules (SM) to achieve a reliability level for a defined target lifetime. Therefore, the best cost-benefit solution for different reliability criteria can be evaluated according to the target lifetime.

Objectives

- Literature review;
- Analysis of MMC fault-tolerance strategies;
- Analysis of reliability modeling;
- Trade-off evaluation between cost and reliability for MMC.

Fraunhofer ISIT

B.Sc. Thesis:

A Thermal Balancing Control for Hybrid Modular Multilevel Converters

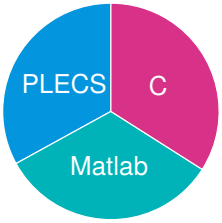
PE 25th anniversary

Requirements

Language
English

Theory
Multilevel Converters ★★★★☆
Power Devices ★★★★☆
Control ★★★★☆
Grids ★★★☆☆

IT-Skills



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Project

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

April 8, 2022

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.

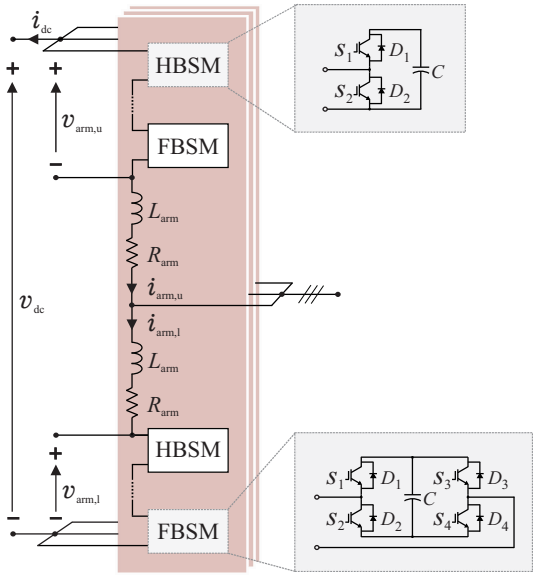


Figure 1: Three-phase topology of HMMC.

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 the ensure a balancing thermal behavior between the power devices in both topologies, avoiding the device failures due to the thermal overstress.

Objectives

- Literature review;
- Analysis of hybrid MMC topologies;
- Proposal of a thermal balance control for hybrid MMC.

Fraunhofer ISIT

MSc. Thesis:

Power Losses Analysis of MV Fast Charging Station

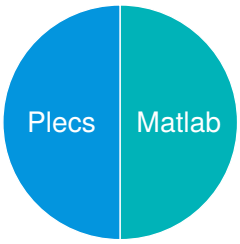
Design of DC-DC Isolated Converters

Requirements

Language
English

Theory
Semiconductors ★★★★☆
SiC and IGBT ★★★★☆
Isolated DC-DC Converters ★★★★☆
Transformers ★★☆☆☆

IT-Skills



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Supervisor:
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Project
BAEW: Laboratory for Reliable Battery-Assisted Energy Conversion

April 18, 2022

Abstract

The electrification of the transportation sector poses the challenge to develop a suitable fast charging station (FCS) for electrical vehicles (EVs). This thesis elaborates a solution for FCSs as shown in the Fig. 1 where direct integration to medium voltage (MV) is realized. You may evaluate the power losses of such a converter with staircase modulation and determine soft-switching boundaries and inductance requirements.

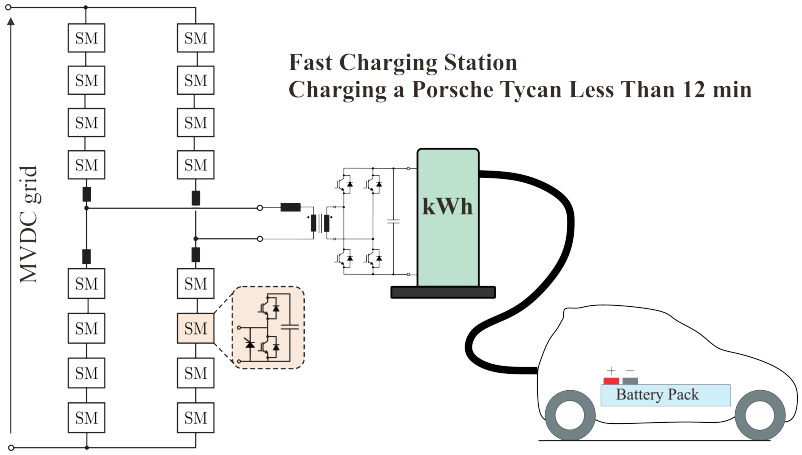


Figure 1: Medium modular multilevel DC-DC converter for fast charging station

Background

FCSs are the indispensable component of the electrification of the transportation. Conventional FCS are connected to AC MV grids by 50Hz transformers which result in large footprint and low efficiency. The topology shown in Fig. 1 is directly connected to the MV grid without 50Hz transformer, therefore power losses, foot-print, and the number of utilized components can be reduced. In this thesis the efficiency of the proposed FCS is maximized considering modulation and the number of cells as the control variables. **The thesis is highly recommended to students who want to join industry or do research in E-mobility sector.**.

Objectives

- Review of literature and previous works
- Analytical analysis of the converter losses
- Implementing Plecs simulation and calculate losses
- Efficiency optimization considering different modulation techniques and as well as number of modules

Reliability on Power Electronics

Fraunhofer ISIT

BSc. Thesis:

Implementation of a Thermal Observer on a Microprocessor

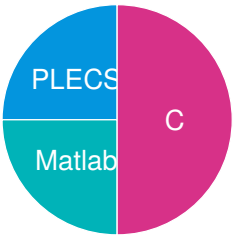
PE 25th anniversary

Requirements

Language
English/German

Theory
Renewables ★☆☆☆☆
Grids ★☆☆☆☆
Power Converters ★★★★★

IT-Skills



Contact

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Supervisor:
Prof. Marco Liserre

April 11, 2022

Abstract

The reliability of power electronic systems is of utmost importance for a save operation of the electrical grid. Assessing the junction temperature of power semiconductors is essential for the reliability assessment. This thesis will focus on the implementation of a thermal observer on a microprocessor.

Background

Thermal observers are a combination of a thermal estimator with a temperature measurement for the correction of the estimation. They provide zero phase lag, low noise as well as the correct temperature, combining the advantages of estimators and temperature measurement. For the implementation in industrial systems the integration of thermal observers in a microprocessor is needed. This Bachelor's thesis will provide the possibility to learn the basics on thermal monitoring of power semiconductors and to acquire of the ability to implement these approaches in a real system.

Objectives

- Basic understanding of thermal observers and their characterization.
- Realization of a thermal observer on a Microprocessor.

Fraunhofer ISIT

MSc. Thesis:

Kalman-Filter based Thermal Digital Twin of Power Semiconductors

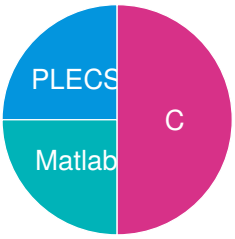
PE 25th anniversary

Requirements

Language
English/German

Theory
Renewables ★☆☆☆☆
Grids ★☆☆☆☆
Power Converters ★★★★★

IT-Skills



Contact

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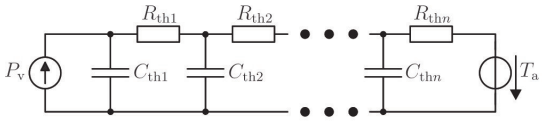
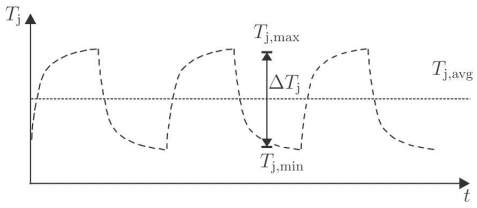
April 11, 2022

Abstract

The reliability of power electronic systems is of utmost importance for a save operation of the electrical grid. Assessing the junction temperature of power semiconductors and the thermal characteristics is essential for the reliability assessment. This thesis will focus on the design and realization of thermal digital twin which is based on a dual extended Kalman filter.





$$\hat{\boldsymbol{x}}_{k|k-1} = f(\hat{\boldsymbol{x}}_{k-1|k-1}, \boldsymbol{u}_k)$$
$$\boldsymbol{P}_{k|k-1} = \boldsymbol{F}_k \boldsymbol{P}_{k-1|k-1} \boldsymbol{F}_k^\top + \boldsymbol{Q}_k$$

$$\tilde{\boldsymbol{y}}_k = \boldsymbol{z}_k - h(\hat{\boldsymbol{x}}_{k\,k-1})$$
$$\boldsymbol{S}_k = \boldsymbol{H}_k \boldsymbol{P}_{k|k-1} \boldsymbol{H}_k^\top + \boldsymbol{R}_k$$
$$\boldsymbol{K}_k = \boldsymbol{P}_{k|k-1} \boldsymbol{H}_k^\top \boldsymbol{S}_k^{-1}$$
$$\hat{\boldsymbol{x}}_{k|k} = \hat{\boldsymbol{x}}_{k|k-1} + \boldsymbol{K}_k \tilde{\boldsymbol{y}}_k$$
$$\boldsymbol{P}_{k|k} = (\boldsymbol{I} - \boldsymbol{K}_k \boldsymbol{H}_k) \boldsymbol{P}_{k|k-1}$$

Background

A digital twin consists of a real time simulation of the system and an optimization algorithm which is fitting the underlying model to optimally represent the physical system based on measurements on it. So, a digital twin can be seen as an observer with adaptive model, realizing the advantages of an observer, such as zero phase lag and noise filtering, as well as giving the possibility for condition monitoring of the system. The thermal behavior of power semiconductors is of high interest, because it is directly linked to their reliability and allows condition monitoring.

Objectives

- Design of a Dual Extended Kalman filter to realize a thermal digital twin.
- Tuning and testing in simulation.
- Implementation on a real time system in the laboratory.

Fraunhofer ISIT

BSc. Thesis:

Active Thermal Control Applied to Power Modules

Thermal cyling: One of the main contributors of power modules degradation

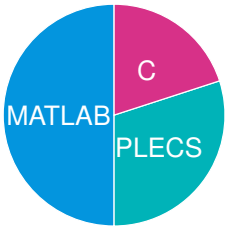
Requirements

Language
English

Theory

Thermal Management	★★★★★
Power Modules	★★★★☆
Control Theory	★★★★☆
Reliability	★★★☆☆

IT-Skills



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Project

n/a

April 11, 2022

Abstract

Monitoring of thermal variables has become key to the development of new control strategies for enhanced reliability of Power Modules (PM). Active Thermal Control (ATC) aims not only to monitor a given temperature of interest, but also to have a certain degree of control over it. In this thesis, power losses will be used as a suitable control action for controlling the junction temperature of a given power module, in order to reduce its thermal cycling.

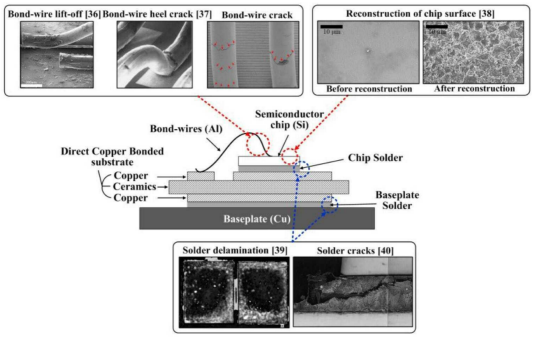

Figure 1: Power module degradation caused by thermal issues.

Background

By means of Condition Monitoring (CM) and Active Thermal Control (ATC), thermal issues that are normally restricting the useful life of the PM can be monitored and controlled respectively. Temperature cycling has a great effect on the reliability of power electronic systems. As a matter of fact, the coefficient of thermal expansion (CTE) mismatch between the elements of a power module (PM) induces mechanical stress, which can result in fractures in the PM substrate, solder degradation, and chip degradation. Furthermore, the cyclic heating and cooling of bond-wires induces fatigue which can leads to their lift-off and fracture. This aging results in particular in an increase of the thermal impedance, and ultimately to catastrophic failure inducing repair and unavailability costs. In this thesis, control strategy where power losses manipulation is used as control action for reducing thermal cycling of PM will be simulated.

Objectives

- Literature review on Active Thermal Control and reliability of power electronics.
- Selected topology system sizing and simulation within its control strategy.
- Dynamic simulation of the proposed system control strategy.
- Possibility of implementing on real-time MCU.