DC Systems, Energy conversion & Storage
Matchmaking Event
14th November 2018
Type of project: MSc thesis

Problem definition:
Due to the increasing penetration of power electronics, harmonic emissions are becoming a prevalent phenomenon in electric power grids. In the case of OWPPs, the concern for power quality is higher due to several reasons. First, the existence of numerous harmonic sources in these systems, which might lead to higher emission levels in steady-state. Second, the fact that OWPPs are typically connected through long submarine cables to the grid, whose high capacitance might interact with the inductance of other elements (e.g., the offshore transformer) creating unexpected resonances at different frequencies and possibly leading to transient instabilities. Consequently, and after having witnessed several severe harmonic events in real OWPPs, the offshore industry is pushing for more research in the field.

Lately, a new method for modelling the wind turbines has appeared: the Impedance Based Method (IBM). The potential of this modelling method is substantial, but before its application in harmonic studies it is necessary to determine its limitations.

Methodology:
- Model a small case study of an OWPP in MATLAB Simulink with detail (PWM model)
- Model the same case study using the Impedance Based Method (IBM)
- Comparison of the two in terms of the harmonic emission accuracy in steady state and of the transient stability and resonance assessment accuracy

Research Objectives:
- Detect the limitations of the IBM for harmonic studies

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OUTPUT IMPEDANCE SHAPING OF THE GRID-SIDE INVERTER IN TYPE IV OFFSHORE WIND TURBINES DUE TO DIFFERENT PHASE-LOCKED LOOP STRUCTURES

**Type of project:** MSc thesis

**Problem definition:**
Due to the increasing penetration of power electronics, harmonic emissions are becoming a prevalent phenomenon in electric power grids. In the case of Offshore Wind Power Plants (OWPPs) the concern for power quality is higher due to several reasons. One of them is the increasing interactions in between power electronic converters and the grid, which lead to resonances and oscillations at different frequencies that might cause problems in the system operation or even the loss of system stability. Consequently, and after having witnessed several severe harmonic events in real OWPPs, the offshore industry is pushing for more research in the field.

More specifically, the possible grid-converter interactions are determined by the passive impedances in the system (such as transformers or cables), the varying impedance in the grid and the output impedance of the Offshore Wind Turbine (OWT) converters (which depends, mainly, on the control structure of the grid-side inverter and the output filter characteristics).

Lately, it has been shown that the PLL in the Grid-Side Inverter (GSI) might have a significant effect in the output impedance shaping of the converter, and thus a notable effect on the harmonic transient stability of the system. It is interesting, then, to study and compare different types of PLL structures.

**Methodology:**
- Develop simulation and theoretical small-signal models of the GSI with different PLLs
- Performance comparison and output impedance influence comparison

**Research Objectives:**
- To find the most adequate PLL structure and design for a typical Type IV OWT

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**Type of project:** MSc thesis

**Scope:**

The two main challenges of meshed low voltage DC grids today are the flexible control of power flow and short-circuit protection. The conventional approach to deal with both problems is to incorporate galvanically isolated DC-DC converters with integrated short-circuit protection, which are rated for the full power rating of the grid. In the previous research, partially rated power flow control converter was proposed in combination with a solid-state short circuit breaker (sscb). This thesis builds on these results.

**Problem definition:**

The sscb is required to operate during all abnormal states of the grid reliably. The crucial part is supplying the auxiliary power to the sscb during faults. The aux. power supply for sscb poses an exciting design challenge. Besides the extreme operational conditions, the power supply needs to be very efficient across a wide input voltage range.

**Methodology:**

In the first phase, the student will get familiar with the design requirements of the sscb for lvdc system. Based on the literature review of the available solutions for the auxiliary power the student selects the best fit for the application. Then proceeds with the design of the prototype power supply.

**Research Objectives:**

- Choose appropriate topology for the sscb aux. power supply
- Design the pcb and integration with the existing sscb
- Experimental verification

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DEVELOP A NOVEL DYNAMIC VOLTAGE DC LINK OPERATION

Type of project: MSc thesis

Scope: It is possible to increase the dc link voltage without increasing the voltage ‘seen’ by the converter switches in a MMC. This improves the efficiency of the system without investing in higher rated components.

Problem definition: Develop a control strategy for operating the dc link with dynamic voltage while keeping the MMC energy within the rated limits to obtain efficiency and capacity improvement.

Methodology: The student is expected to prove this idea through simulations and implement it experimentally in the available lab scale converter. The fundamental equations \(^1\) will be given to the student for the implementation of this concept, for which familiarity with MATLAB is important.

Research Objectives:

- Show through simulations that the energy in the MMC can be controlled such that the dc link voltage can be dynamically raised without increasing the voltage seen by the submodule capacitors and switches.
- Define boundaries within which this concept can be applied.
- Determine the achievable efficiency/capacity gains of operating the MMC with dynamic dc link voltage.
- Implement the concept in the available lab-scale MMC prototype to justify the claimed gains.

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\(^1\) Refer conference paper: “Modular Multilevel Converter Performance with Dynamic MVDC Distribution Link Voltage Rating” in 18TH International Conference on Power Electronics and Motion Control At: Budapest, Bulgaria
DEVELOP MODULAR MULTILEVEL CONVERTER BASED ANCILLARY SERVICES FOR THE DISTRIBUTION GRID

Type of project: MSc thesis

Scope: This project explores the use of modular multilevel converter (MMC) for harmonic elimination\(^2\). The concept is to be applied to mitigate the power quality issues and highlight the trade-offs and challenges therein.

Problem definition: Develop schemes to detect and mitigate medium voltage grid current and voltage harmonics by operating a MMC as STATCOM. Different harmonic detection and current injection strategies need to be implemented and compared in terms of power quality conditioning.

Methodology: Simulations as well as experimental work is desired. The student is expected to learn about the operation of the MMC and develop control techniques to comply with different grid requirements at medium voltage level.

Research Objectives:

- Identifying the methodology to detect harmonics at the point of common coupling (PCC).
- Determining how fast the convertor needs to react while keeping its internal balancing.
- Showing the operation of MMC as STATCOM for harmonic elimination experimentally.
- Compare different methods of achieving harmonic elimination using MMC and 2 level VSC.

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RESTRICTURE EXISTING DISTRIBUTION GRIDS WITH FLEXIBLE DC LINKS

Type of project: MSc thesis

Scope: The existing ac link between two substations needs to be converted to partial dc link system. Think of how to interconnect the system to have maximum infrastructural utilization and showcase the operational modes of the new system. Provide grid support to the distribution network using this flexible ac-dc link.

Problem definition: Design and simulate a grid integrated flexible dc link for power redirection, reactive power support, harmonic elimination and other ancillary services to improve the operability of the existing medium voltage ac distribution network.

Methodology: Ability to simulate state space model and control strategies in MATLAB is required. Understanding of modular multilevel converters (MMC) is to be developed. Enthusiastic student may use the available laboratory prototypes to implement his/her findings.

Research Objectives:
- Show how parallel ac-dc link topology can operate with converter based voltage regulation.
- Develop various grid supporting ancillary services using MMC, such as active power redirection, reactive power support, fault ride through, harmonic elimination, etc.
- Prove the working of the developed optimal ac-dc load sharing algorithm.
- Analyse the proposed system feasibility with an economic/functionality study.

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LEARNING WITH THE LAB-SCALE MODULAR MULTILEVEL CONVERTER

Type of project: Extra Project

Scope: The available lab scaled modular multilevel converter (MMC) can be used to gain knowledge on real time digital simulator (OPAL-RT) and other hardware operation.

Problem definition: Experiment with the available lab-scaled MMC to understand the operation principles. Its operation will then be tested by applying different control strategies.

Methodology: Laboratory work is expected.

Research Objectives:

- Learn and test different PWM techniques and generate the required carrier wave to switch the submodules.
- Apply simple control schemes, for instance capacitor balancing to test the proper operation of the available lab-scale MMC.

Collaboration with Industry: <No>

Contact details:

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DC/DC SOLAR CONVERTER FOR TROLLEY GRID APPLICATIONS

Type of project: Extra Project/ SIP 2(Possibility of extension as master thesis)

Scope:
With the increasing awareness and hence, the demand for renewables energy has led to the integration of more and more solar because of its world-wide availability. Integrating solar PV panels with new power electronics converters is trendy at the moment and being researched.

Problem definition:
- Investigation of state of the art for DC/DC solar converters
  - What are the new switches/devices available in the market and their pros & cons?
- How can the power density be increased?

Methodology:
- Literature review of current DC/DC converter topologies and the current materials in the market.
- Reviewing the control methodologies of the control of the Solar converter
- Designing the layout for the converter in Altium/EAGLE.
- Submitting a report
- Possibility of extension of the work for master thesis for hardware implementation

Research Objectives:
Investigating the state of art thoroughly and checking the possibility to work upon the new dimension of improvement. There is a possibility of publishing a conference paper.

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TESTING OF BIDIRECTIONAL FLYBACK CONVERTERS FOR ENABLING POWER-SHARING IN RURAL DC MICROGRIDS

Type of project: SIP2/Extra Project

Scope: Recent developments in off-grid rural electrification have been largely based on the use of Solar Home Systems (SHS). Going forward a lot of energy services will be enabled through interconnection of these SHSs to form rural microgrids.

Problem definition: Interconnection of SHSs would necessitate the necessary power electronics hardware that will enable the power conversion needed between the different voltage levels prevalent in the DC grid. The project will focus on the hardware testing of multiple bidirectional flyback converters rated around 300 W.

Methodology: The project will build upon an existing hardware design for the converter, where a thorough design of the converter topology and hardware has been previously built. The project will focus on testing of multiple such converters.

Research Objectives:

- Hardware testing of multiple bidirectional flybacks
- Power sharing between multiple converters in a DC nanogrid lab setup

Collaboration with Industry: No

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**Type of project:** MSc thesis

**Developing Safer and More Reliable Solar Inverters for Smart Houses**

**Scope:**
To study, design and construct a transformer-less single-phase photovoltaic inverter which features low common-mode noise emission.

**Problem definition:**
Currently, transformer-less photovoltaic (PV) inverters are widely found in the energy market because of the inherent benefits in cost reduction and power efficiency enhancements when compared to galvanic isolated versions. In such circuit concept lower impedance from the high voltage potentials to the ground exists. Therefore, Common-Mode (CM) voltages can reduce life-time of the PV panels as leakage current can flow through its stray capacitances to the ground degrading the insulation materials. Additionally, it can generate a health hazard for personal involved in the maintenance of the PV system as the leakage current can flow through their body.

**Methodology:**
To study, simulate, design, construct and test a power electronics inverter using computational tools and TU Delft’s laboratory facilities.

**Research Objectives:**
- Literature review of transformer-less PV inverter with low CM voltage emission
- Benchmark suitable inverter solutions using multi-objective design approach
- Design and construct a single-phase PV inverter solution with Low CM emission
- Test the constructed prototype

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Type of project: MSc thesis

Scope:

Study, design and implementation of a grid interface circuit or AC-DC converter featuring DC active pulsating power buffer for electrolytic less two power stage charging of Electric Vehicles (EV).

Problem definition:

The Electric Vehicle (EV) charging market is very dynamic. The so called AC-type chargers can be found confined within the vehicle or on-board. This must be able to withstand the harsh environment with ambient temperature of above 75 °C. Therefore, compact and high-efficiency power electronics and implementing electrolytic-less capacitors in the power range of 6 kW .. 12 kW is desired. The operation of the grid-connected power stage with DC active power buffer has become standard in high compact systems. More importantly, this solution eliminate the requirement of high energy storage in the DC-link because the pulsating power is compensated leading to an electrolytic less capacitor design. As the life-time of the power converter in high temperature environments is typically limited by the usage of the electrolytic capacitor technology, a more reliable system is finally obtained with the active pulsating power buffer.

Methodology:

To study, simulate, implement an active pulsating power buffer for EV charging applications. Means to incorporate the power buffer within the AC-DC or DC-DC converter stages will be investigated. The optimum technology for the active power buffer will be tested in an existing AC-DC power converter.

Research Objectives:

- Literature review in high efficiency and ultra-compact power AC-DC conversion systems;
- Investigation and proposal of active pulsating power buffers at the front- or back-end circuit;
- Implementation of a control strategy for the studied circuit in an existing TI DSP control board;
- Test the developed study in an existing prototype.

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Type of project: MSc thesis

Scope:

Study, design and implementation of a grid interface circuit or AC-DC converter featuring Triangular Current Modulation (TCM) for two power stage charging of Electric Vehicles (EV).

Problem definition:

The Electric Vehicle (EV) charging market is very dynamic. The so-called AC-type chargers can be found confined within the vehicle or on-board. This must be able to withstand the harsh environment with ambient temperature of above 75 °C. Therefore, compact and high-efficiency power electronics (and implementing electrolytic-less capacitors) in the power range of 6 kW .. 12 kW is desired. The operation of the grid-connected power stage with triangular current modulation and phase-shift interleaving has become standard in high compact and high efficiency systems. The required large current ripples across the magnetics allows the operation of the bridge-legs of the circuit with Zero-Voltage Switching (ZVS), leading to the utilization of smaller passives and cooling systems. Unfortunately, variable switching frequency operation is required and means to limit the frequency range are necessary in a digital implementation with the latest microcontrollers available in the market. The addition of passive networks and/or the use of modified TCM algorithms have shown promising results.

Methodology:

To study, simulate, implement a narrow frequency range triangular current modulation in a TI DSP. The functionality of the developed software will be tested in an existing AC-DC power converter.

Research Objectives:

- Literature review in high efficiency and ultra-compact power AC-DC conversion systems;
- Investigation and proposal of TCM techniques narrowing switching frequency range;
- Implementation of a developed TCM modulation in an existing TI DSP control board;
- Test the developed software in an existing prototype.

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FUTURE DC TRANSMISSION GRIDS: STUDY AND IMPLEMENTATION OF OPTIMUM PULSE PATTERN (OPP) MODULATION AND PREDICTIVE CONTROL

Type of project: MSc thesis

Scope:
Study and implementation of MMC for future DC-type Transmission using intelligent control algorithms based on predictive control and optimum pulse pattern modulation.

Problem definition:
The modular multilevel converter or MMC is one of the favourable circuits for implementing DC-type medium or high voltage distribution/transmission. The high number of serial circuit cells brings advantages in terms of harmonic performance but complexity for capacitor voltage control. Optimum Pulse Pattern modulation has shown superior performance than PWM techniques when the switching frequency is only few times higher than the fundamental. Predictive control technique is also a powerful tool to enhance system performance specially when the allowed processing time is large enough. The combination of both techniques can bring many operational advantages for the MMC.

Methodology:
To study, simulate, design and test the usage of OPPs and predictive control in a MMC using computational tools and TU Delft’s laboratory facilities.

Research Objectives:
- Literature review of usage of predictive control and optimum pulse pattern in MMCs;
- Derive analytical models for MMC verifying operational performance merits such as harmonic injection, capacitor cell voltage balance, circulating currents, component losses, etc;
- Benchmark the developed OPPs against conventional modulations, e.g. nearest level, PWM phase-shift/disposition, Space Vector, etc;
- Implement the developed study in the MMC hardware demonstrator.

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**DESIGN OF TEST BENCH FOR STATIC AND DYNAMIC CHARACTERIZATION OF WIDE BANDGAP SEMICONDUCTORS**

**Type of project:** MSc thesis

**Scope:**
To study, design and construct a test bench for characterization of wide bandgap semiconductors.

**Problem definition:**
Silicon Carbide (SiC) based semiconductors are seen as the future of power electronics. When compared to Silicon (Si) based devices higher voltages and frequencies are possible enabling smaller and more efficient power systems. The switching performance enabled by the extremely high dv/dt and di/dt create complexity for device accurate dynamic characterization. Current and voltage probes with very high bandwidth are necessary. Additionally, special care with both, the parasitic inductances within the commutation loop and the gate driver power capability are necessary. Those challenges must be overcome in order to provide meaningful input data to the power electronics designer.

**Methodology:**
To study, simulate, design, construct and test a semiconductor test bench with double pulse features programmable with Texas Instruments DSPs. This will be used to compare the measured performance to data sheets of commercially available SiC Mosfets.

**Research Objectives:**
- Literature review of static and dynamic semiconductor tester
- Benchmark suitable current and voltage probes with large bandwidth
- Design and construct a test bench, where the temperature for the tested devices can be controlled

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DEVELOPING INTELLIGENT GATE DRIVERS WITH ULTRA-FAST SHORT-CIRCUIT DETECTION FOR HIGH PERFORMANCE SEMICONDUCTOR TECHNOLOGY

Type of project: MSc thesis

Scope: To design and construct a high-side gate driver for Silicon Carbide (SiC) MOSFETS with high voltage isolation and common-mode noise rejection featuring ultra-fast short-circuit detection.

Problem definition: Silicon Carbide (SiC) based Metal-Oxide Semiconductor-Field-Effect Transistors (MOSFETS) are widely praised as the future of high-end power converters due to their improved performance over conventional Silicon (Si)-based devices. To unlock the full potential of the SiC technology high-speed gate driver circuitry are necessary to reduce the time of the commutation dynamics of the MOSFET and thus reduce the energy dissipated during each switching action. This operational benefit results in an increment of the Electromagnetic Interference (EMI) caused by the consequent high dV/dt and di/dt of the switching mechanism. More importantly, EMI issues can degrade the breakdown capability of the insulation materials and cause instability and unexpected behaviour of the control circuitry. Finally, ultra-fast short-circuit detection and the respective corrective action must be implemented in order to protect both the power converter and their connected sensitive loads. In today’s commercial available SiC MOSFETS a short-circuit action can lead to over-current in the excess of 10x the rated value within 10µs, which implied that the detection circuitry + the reaction time to a short-circuit event must be ideally within < 1 µs.

Methodology: To study, simulate, design, construct and test an intelligent gate driver using computational tools.

Research Objectives:
- Literature review of high-voltage gate drivers and fast short-circuit detection
- Design and construct an intelligent gate driver
- Test the constructed prototype

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Type of project: <MSc thesis>

Scope: Design a position sensorless control scheme for the high-speed permanent synchronous machine of the flywheel energy storage system

Problem definition:

In the flywheel energy storage system, the charging part is actually to control the high-speed motor. Here we adopt a permanent magnet synchronous machine (PMSM) due to its high efficiency and high power density. Due to the digital processor applied, it is preferable to design the controller including the current loop and speed loop regulator directly in the discrete-time domain to obtain high dynamics and ensure stability. On the other hand, the controller design also includes the design of the observer/estimator of position and speed. Generally, the flywheel operates at high speed whereas it stays at a lower speed during start-up for a relatively long time due to its high inertia. The sensorless scheme should be adaptive from start-up to high-speed operation. Besides, the controller should be robust to deal with some parameter uncertainties and disturbance. Control algorithms will be simulated and verified in the MATLAB/Simulink first and then downloaded to the TI DSP to realize in the experimental setup.

Methodology:

- Build the mathematics model of the PMSM,
- Based on the model, design the control scheme in terms of the control theory;
- Do the simulation and realize in the experimental setup.

Research Objectives:

- High-performance controller design including current, speed regulation and position observer;
  Simulation; Laboratory prototype testing

Contact details:

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ACTIVE ACOUSTIC NOISE REDUCTION OF PERMANENT MAGNET SYNCHRONOUS MACHINE

Type of project: MSc thesis

Scope: Reduce electromagnetic excited noise emitted from permanent magnet synchronous machine using active control method.

Problem definition: Comfortable user experience requires electric machine to be quiet in a wide speed range for different applications, e.g. electric vehicle and home appliances. Currently unpleasant vibration and noise from the electric motor is reduced by auxiliary approaches such as attenuation or absorbance. If the vibration and noise problem could be solved by active control of electrical machines, it will save the overall cost and reduce the system size.

Methodology: Existing modelling technique will be improved and applied to investigate methods for electromagnetic excited acoustic noise reduction. Different modulation techniques, and dv/dt filters will be investigated. Based on the selected methods, simulations will be carried out to compare the performance. Selected control methods will be implemented on an existing motor drive.

Research Objectives:

- Acoustic noise modelling of electric machines.
- Investigate and compare different approaches for noise reduction through control.
- Implement active noise reduction control algorithm in an existing setup.

Collaboration with Industry: No

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Type of project: MSc Thesis

Scope: This project aims at design a dv/dt filter for a permanent magnet synchronous machine (PMSM) drive and adapt the machine control algorithm to consider the effect of dv/dt filter.

Problem definition: PMSM drives are widely used in modern industry, consumer electronics and household. In the request for higher power density, high speed semiconductors (IGBT, SiC or GaN) are employed to drive the PMSM, which results in fast rise time voltage pulses by pulse width modulation (PWM) techniques. Unfortunately, it creates a number of problems to the drive system, which include over voltage, parasitic earth current, harmonics, acoustic noises, and eddy current losses. By applying the dv/dt filter between the inverter and the PMSM can help relieve the problems, however, it affects the machine dynamics. Control method, e.g. the rotor flux observer must be adapted to consider the effect brought by the dv/dt filter.

Methodology: Dynamic models of dv/dt filter in PMSM drive will be built. Simulation will be used to design the dv/dt filter and evaluate its effects on control. Control algorithms considering the dv/dt filter will be implemented in an existing setup.

Research Objectives:
- Design of a dv/dt filter for a PMSM drive
- Dynamic modelling of dv/dt filter and the PMSM drive with it
- Control algorithm of PMSM considering the dv/dt filter

Collaboration with Industry: No.

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DESIGN AND OPTIMIZATION OF ELECTRIC MACHINE FOR ELECTRICALLY ASSISTED SHORT–RANGE CIVIL AIRCRAFT

Type of project: MSc Thesis

Scope: Facing the environmental pressure, the aviation industry has to come up with innovative technologies to reduce its environmental footprint. An electrically assisted propulsion system (EAPS) which embeds an electrical machine in a conventional turbofan engine can reduce the size and emission of the engine, and increase the overall efficiency.

Problem definition: The thesis project aims to design a high power density electrical machine which can operate in parallel with the turbofan engine for short-range mission. Requirements of electrical machines will be investigated from mission profile, in cooperation with aerospace engineering faculty. Tradeoff between reliability, efficiency and power density should be made with a preliminary design tool set. Physics based model should be built for detailed design and analysis of the electrical machine.

Methodology: The project includes electrical machine modelling and simulation based on FEA, circuit and analytical calculation.

Research Objectives:
- Integrative design of electrical machine based on mission profile.
- Development of preliminary design tool set for electrical machines in EAPS.
- Physics based modelling of PM machine for EAPS.

Collaboration with Industry: No.

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HARDWARE-IN-LOOP SIMULATION OF ELECTRIC VEHICLE POWERTRAIN

Type of project: MSc Thesis

Scope: This project aims at development of a hardware-in-loop simulation system of electric powertrain of electric vehicles.

Problem definition: Hardware-in-loop (HIL) or power-HIL simulations are essential for cost-effective and time-effective developments of modern powertrains in electric vehicles and electric aircrafts. Control algorithms can be tested through mathematical dynamic models of electrical machines and power electronics without building real prototypes. The models of power electronics converters can be replaced with real converters to be tested if power-HIL is involved. To fully represent the dynamic performance of the powertrain, magnetic saturation, losses and temperature rise of motors, dynamics of the transmission system, battery and vehicle aerodynamics should be considered. Comprehensive models should be built and integrated in the real time simulation platform. Control method implemented in an external control board will be validated by the real time model. Various driving profiles and control algorithms will be investigated to validate the effectiveness of the developed models.

Methodology: Dynamic models of electrical machines considering saturation will be developed. MATLAB/Simulink and OPAL-RT will be used to implement the real-time simulation. Control algorithms will be implemented in an external control board.

Research Objectives:
- Design and implementation of interfaces between the control board and OPAL-RT
- Dynamic modelling of different components in EV powertrain
- Real time simulation platform of EV powertrain
- Control algorithm investigation using developed simulation platform

Collaboration with Industry: No.

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APPLICATION SCENARIOS SIMULATION FOR DYNAMIC INDUCTIVE POWER TRANSFER SYSTEM

Type of project: MSc thesis

Scope: In the dynamic wireless charging process, the inductive power transfer (IPT) system performances as the intermedia between moving EVs and power grid. The health of the batteries on board depends on the power rating and quality of the dynamic IPT system. On the other hand, the dynamic IPT system accounts for a non-negligible part of the power from power grid. It is necessary to investigate the system level impact of dynamic IPT system on EVs and power grid.

Problem definition: Due to the deployment of transmitters and variations of coupling coefficient, the power transfer varies during the charging process, which has obvious effect on the battery lifetime. Besides, in different driving cycles like aggressive and highway modes, the power consumption and factor of dynamic IPT system may differ. The research will simulate the performance of dynamic IPT system with a certain topology, thus to figure out its physical limitations and design constraints in different application scenarios.

Methodology:
- Literature review of basic principles and topologies of dynamic IPT system
- Simulations of the charging performance of dynamic IPT system in different application scenarios
- Analysis of interactions of dynamic IPT system with power grid and battery lifetime

Research Objectives:
- Simulation models proposing the constraints and limitations of dynamic IPT system
- Design concerns regarding the influence on battery lifetime and power grid
- Suitable application scenario for dynamic IPT system

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FOREIGN CONDUCTIVE OBJECTS MODELLING FOR DYNAMIC WIRELESS CHARGING OF EV

Type of project: MSc thesis

Scope: As an approach to mitigate the range anxiety and bulky battery packages of EVs, dynamic inductive power transfer (IPT) for EVs charging attracts lots of attention. Conductive objects like coins and cans are very likely to occur on the road, and performances of dynamic IPT system can be affected if these objects placed between transmitters under roads and pick-ups on board.

Problem definition: When conductive objects are placed near or in the magnetic field produced by dynamic IPT system, eddy current will be generated. This eddy current could lead to power loss and change in magnetic field and electrical waveforms. Modelling should be done to evaluate if conductive objects having limited size could affect the efficiency and modify the waveform of the electrical variables in the dynamic IPT system.

Methodology:
- Literature review of the foreign conductive objects analysis for the dynamic IPT system
- Analytical analysis of the power loss caused by eddy current
- Electromagnetic model of the dynamic IPT system with the presence of conductive objects.

Research Objectives:
- Modelling method for the evaluation of the effect of foreign conductive objects
- Guideline for the design to mitigate the adverse effect of foreign conductive objects
- (OPTIONAL) Method for foreign conductive objects detection

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MULTI-OBJECTIVE OPTIMIZATION FOR DYNAMIC WIRELESS CHARGING OF EV

**Type of project:** MSc thesis

**Scope:** Recently, dynamic inductive power transfer for EVs charging has received a great deal of attention. This technology enables moving EVs to pick up power from transmitting devices installed under the road. Therefore, range anxiety, one of the main technical problems of EVs, can be significantly alleviated, and the weight and volume of batteries on board can also be reduced.

**Problem definition:** As a loosely-coupled power transfer system, special attention should be paid to the power level and the efficiency of the dynamic IPT system, which depend heavily on its operation state, including the lateral misalignment, driving speed, air gap and temperature. Also, the total cost of the system is important to be considered. This research focuses on multi-objective optimization that can yield low cost, high efficiency at high power density.

**Methodology:**

- Literature review of the topologies of the coil and the compensation of dynamic IPT system
- Electromagnetic model and analytical analysis of a multi-coil dynamic IPT system
- Multi-objective optimization considering different operation factors.

**Research Objectives:**

- Optimal topology of the coils and compensation circuits
- Guideline of the deployment of the transmitting coils under roads
- Mathematic method calculating the maximum power and efficiency of dynamic IPT system

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**SMART BI-DIRECTIONAL WIRELESS IPT SYSTEM FOR V2G APPLICATIONS**

**Type of project:** MSc thesis

![Image](image_url)

**Fig 1:** (a) Wireless IPT charging for smart house, (b) smart charging with V2G and V2H capability

**Scope:** Analysis on V2x possibilities/smart charging, resonant converter control and lab work on existing setup to ensure high efficiencies with bi-directional power flow.

**Problem definition:** The possible flexibilities and potential of wireless charging makes it a prime candidate of replacing conventional wired charging of EVs. Additionally, they can provide emergency back-up power and ancillary services via V2H and V2G capabilities respectively. The main research challenge in this field is to develop a robust control system to ensure bi-directional power flow and maintain high efficiency.

**Methodology:** The methodology to arrive at a good design and control method are the following:

- Literature review of bi-directional control for resonant converters
- Develop a dynamic model of the IPT system
- Design the controller in simulation and validate the operation via existing laboratory prototype

**Research Objectives:** The pertinent research objectives are highlighted below:

- Stability analysis of a IPT system and draw guidelines
- Develop a control strategy to stably control power flow in both directions
- Implement bi-directional control on an laboratory prototype

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COUPLING CO-EFFICIENT ESTIMATION FOR DYNAMIC WIRELESS CHARGING IPT SYSTEM FOR EV MISALIGNMENT TOLERANT CHARGING

Type of project: MSc thesis

Scope: Evaluating possible methods for dynamic coupling coefficient estimation, with possible lab verification.

Problem definition: The possible flexibilities and potential of wireless charging makes it a prime candidate of replacing conventional wired charging of EVs. In general, IPT systems suffer from lower efficiencies during misaligned operations which can be improved via dual side control. However, dual side control requires an accurate estimation of the coupling co-efficient online. The main research challenge in this field is to develop a robust method to estimate the coupling co-efficient of IPT magnetic couplers online and accurately.

Methodology: The methodology to arrive at a good design and control method are the following:

- Literature review of estimation of coupling co-efficient in magnetic structures
- Study existing methods and analyse their advantages, disadvantages and complexity
- Design the novel method (using Kalman filters, machine learning based approach) to estimate the coupling accurately

Research Objectives: The pertinent research objectives are highlighted below:

- Uncertainty quantification of coupling estimation based on parameters
- A robust method of estimating coupling along with laboratory implementation

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DEVELOPING ADVANCED ELECTRIC VEHICLE TRACTION SYSTEM USING PARALLEL CONNECTION OF SI AND SiC BASED SEMICONDUCTORS

Type of project: MSc thesis

Scope:
To optimize the utilization of parallel Si IGBTs and SiC MOSFETs in Electric Vehicle traction systems.

Problem definition:
Power electronic converters are the future of transportation. Many countries have announced banning future sale of passenger vehicles powered by fossil fuels within the next 20-30 years. Presently all major automotive companies are developing their own hybrid or full electric vehicle (HEV/EV) technologies. The power inverter used in the electric traction system must be able to cope with the load profile of the vehicle, which critically requires a high power intake when the EV is accelerating, e.g. during few tens of seconds. On the other hand, the longer operating times occurs during cruise speeds which constitutes a partial load operation. The utilization of parallel Si IGBT and SiC Mosfet constitutes a good compromise between power efficiency performance and cost. Moreover, the high current capability of the Si IGBT and low switching losses of the SiC MOSFETs ensures a better utilization of the cooling system. The sizing of the semiconductor chip areas is an optimization problem.

Methodology:
To study, simulate, design, construct and test an Electric Vehicle traction system.

Research Objectives:
- Literature review of EV Traction System;
- Optimize the usage of SiC Mosfet and Si IGBT chip areas according to the power;
- Benchmark, design and construct a downscaled EV traction system
- Test the constructed prototype

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DEVELOPING THE NEXT GENERATION OF ELECTRIC VEHICLE BATTERY CHARGERS BASED ON ISOLATED DIRECT AC-TO-DC CONVERSION TECHNOLOGY

Type of project: MSc thesis

Scope:
To study, simulate, benchmark, design and construct a single-stage (or direct) isolated electric vehicle fast charger concept.

Problem definition:
The Electric Vehicle (EV) charging market is very dynamic. Companies and institutes involved in the research and development of this area are devoted to considerably reduce the EV charging times to be close to the ones spent by users in gas-stations filling the fuel of the internal combustion engines vehicles (ICEVs). Today most EVs can be charged at 50 kW@400V following the fast charging standards “CCS - up to 80kW@400V” and “CHAdeMO – approx. 50kW@400V”. However new EVs are designed to withstand much higher power, e.g. Porsche Mission-E 300 kW, and due to the current limitation of the battery cells, higher battery bank voltages will be used, e.g. up to 1 kV. Due to safety reasons the EV battery must be galvanic isolated from the public AC grid. Additionally, the pursue for high power efficiency, low cost and the desire for EV charging stations which are fit to deliver power to wide range of battery voltages, i.e. 200 .. 1kV, makes the direct AC-to-DC power conversion technology especially suited.

Methodology:
To study, simulate, design, optimize, construct and test a high efficiency EV charger using computational tools and TU Delft laboratory facilities.

Research Objectives:
- Literature review of fast EV chargers
- Simulate, benchmark, design and construct an advantageous EV charger solution
- Test the constructed prototype

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HARDWARE-IN-LOOP SIMULATION FOR ELECTRIC VEHICLE CHARGING IMPACT ON DISTRIBUTION GRID

Type of project: MSc thesis

Scope:
This project aims at developing a hardware-in-loop (HIL) simulation system for Electric vehicle (EV) charging in distribution network, and simulate the impact of EV charging on the grid.

Problem definition:
HIL is a cost-effective and time efficient method to implement large-scale grid experiments. In this system, a power amplifier, an AC charger and a battery will be connected to the simulator to model the real charging environment. OPAL-RT will be employed as the HIL platform.

Methodology:
The student is expected to develop a grid model, build up the OPAL-RT facility and run the simulation in the system. Implement a simple smart charging algorithm, compare the impact of controlled/uncontrolled EV charging on the distribution grid.

Research Objectives:
- Develop distribution network model for EV charging
- Design and set up the OPAL-RT HIL simulation system
- Real-time simulation and compare the controlled/controlled EV charging in distribution network

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Source: OSCD, Elaad
# NOVEL DECOUPLING CONTROL STRATEGY OF MIMO CONVERTERS

**Type of project:** MSc thesis

**Fig1:** (a) Quad–active bridge converter, (b) MIMO control loops with decoupling compensator

**Scope:** An integrated multi-port converter, which utilizes a single power conversion stage to interconnect all ports, instead of the individual dc-dc conversion stages, can be introduced in order to make the whole grid simpler. However, multiple input multiple output (MIMO) converters require complex control strategies to decouple the current control loops to control the power flows.

**Problem definition:** The research challenge in this field is to develop a robust decoupling control strategy which decouples the power flows between different ports.

**Methodology:** The methodology to arrive at a good control algorithm are the following:

- Literature review of advanced decoupling control for MIMO systems
- Develop the small signal model of a MIMO converters and validate experimentally
- Design a decoupling control strategy and compare the results with traditional feedforward decoupling control

**Research Objectives:** The pertinent research objectives are highlighted below:

- Small signal model of the MIMO converter
- Uncertainty quantification of parameters on the control algorithm
- Quantification of performance benefits compared to traditional decoupling control

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SMART POWER MANAGEMENT ALGORITHMS WITH FORECASTING FOR MULTI-PORT CONVERTER BASED DC GRIDS

Type of project: MSc thesis

Scope: Future DC residential grids will be built with multi-port converters (MPC) as the backbone. An integrated multi-port converter, which utilizes a single power conversion stage to interconnect all sources and storages like EVs can be optimally controlled to satisfy multiple objectives like peak shaving, cost minimization and ancillary services.

Problem definition: The research challenge in this field is to design smart algorithms for QAB converter (MPC with four ports) capable of V2G and V2H.

Methodology: The methodology is comprised of the following:

- Develop load flow model of a DC grid with MPC
- Smart charging of integrated EVs and deriving a holistic cost function
- MILP/ MINLP formulation of the algorithm and implementation

Research Objectives: The pertinent research objectives are highlighted below:

- Quantifying the benefits of a MPC based DC microgrid in terms of providing ancillary services
- A smart algorithm which controls power flows depending on scenarios
- Estimate the economic impact of such algorithms in different case studies

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DC FAULT RIDE-THROUGH OF A QUAD-ACTIVE BRIDGE CONVERTER BASED DC NANOGRID

Type of project: MSc thesis

**Fig 1**: Quad–active bridge converter based ring DC grid for buildings

**Scope**: DC fault ride-through capability (FRT) is a highly desired feature of QAB converters interfacing a DC house and a dc distribution grid. It is required to (a) ride through the fault at even 0 V, (b) transfer the highest possible power to connected loads and support the voltage in the house grid, and (c) fast dynamic control.

**Problem definition**: The research challenge in this field is to develop control strategy which can realize all the objectives w.r.t FRT capabilities.

**Methodology**: The methodology to arrive at a good control algorithm are the following:

- Literature review of fault-ride through capabilities of converters
- Develop dynamic model of a MIMO converter and the associated dc distribution grid
- Comprehensive dc fault analysis of the state-of-the-art modulation schemes

**Research Objectives**: The pertinent research objectives are highlighted below:

- Develop optimal modulation scheme for extending soft switching range and FRT capability
- Performance of variable switching frequency as a fault-limiting strategy
- Laboratory implementation of the modulation scheme on a QAB prototype

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DESIGN OF MULTI-WINDING TRANSFORMER FOR QAB CONVERTER

Type of project: MSc thesis

Scope: DC residential grids consist of multiple sources and bi-directional loads. An integrated multi-port converter, which utilizes a single power conversion stage to interconnect all ports, instead of the individual dc-dc conversion stages, can be introduced in order to make the whole grid simpler. Thus, cost, size, and volume can be reduced due to less amount of devices and associated circuits. The reduced conversion step results in higher power density and efficiency.

Problem definition: The research challenge in this field is to optimally model and design the high frequency transformer to couple all the windings of the QAB converter.

Methodology: The methodology to arrive at a good design are the following:

- 3D and 2D FEM model of the transformer
- Detailed loss model and evaluation power density limits of the transformer

Research Objectives: The pertinent research objectives are highlighted below:

- A simplified equivalent circuit of the HF transformer
- Loss model of the HF transformer
- Multi-objective optimization and laboratory implementation

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**Type of project:** Extra Project/ SIP 2 (Possibility of extension as master thesis)

**Scope:**
1. Currently, the efforts are being made to store recuperated braking energy of the electric vehicle in trolley grid and the energy storages should be connected to the grid by bidirectional DC/DC converters. 2. There are currently no chargers which can be used to charge multiple vehicles of different rating e.g. car, bus, truck etc

**Problem definition:**
- Investigation of state of the art for DC/DC bidirectional converters for the above two.
  - What are the new switches/devices available in the market and their pros & cons?
- What are the charging algorithms for charging storage and multipurpose infrastructure?
- How can the power density be increased?

**Methodology:**
- Literature review of current DC/DC converter topologies & the current materials in market.
- Reviewing the control methodologies/algorithms of the control of the existing converters.
- Designing the layout for the converter in Altium/EAGLE and submitting a report
- Possibility of extension of the work for master thesis for hardware implementation

**Research Objectives:**
Investigating the state of art thoroughly and checking the possibility to work upon the new dimension of improvement. There is a possibility of publishing a conference paper.

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POWER FLOW CONTROL IN LVDC GRIDS USING PARTIALLY RATED POWER FLOW CONTROL CONVERTERS

Type of project: MSc thesis

Scope:
Generally, future distribution grids lack the robustness and inertia of current AC systems. Therefore, additional control is necessary to ensure appropriate operation. For example, the power flow in multi-terminal dc grids needs to be controlled to achieve efficient operation. In this thesis, a partially rated power flow control converter (PFCC) will be used to achieve this goal.

Problem definition:
The primary goal of the thesis is the development of a control algorithm for PFCC’s in multi-terminal LVDC networks. The primary objectives of the decentralized algorithm should be able to prevent local overloads and excessive currents in distribution lines without utilizing communication.

Methodology:
Large-signal PFCC and LVDC grid models are available to be used in Matlab/Simulink. These models allow fast deployment of complex systems. Besides simulations, the results will be verified in a laboratory-scale microgrid.

Research Objectives:
- Review of decentralized power flow control algorithms in DC systems
- Development of a power flow control algorithm for PFCC’s in LVDC grids
- Simulations of the proposed power flow control algorithms
- Experimental verification of the proposed algorithms

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MODELLING, STABILITY, CONTROL AND MANAGEMENT OF DC GRIDS

Type of project: MSc thesis

Scope: To aid the broad adoption of DC distribution grids more research is required on the modelling, stability, control and management of dc distribution grids. Many topics within these categories are available for master students.

Problem definition: Distribution grids are subjected to changes such as the increasing participation of distributed energy resources (DER), segmentation of the grid (for example into microgrids), and increasing participation of prosumers. This poses significant challenges with respect to stability and control. It becomes attractive to employ DC distribution systems since they have several advantages to AC distribution systems. DC distribution grids do not require the synchronization or reactive power governance, and do not have issues with harmonic and inrush currents. Moreover, the interconnection of dc (micro)grids is significantly simpler. Furthermore, dc distribution grids are also foreseen to have advantages over ac in terms of efficiency, distribution lines, and converters.

Methodology: These topics mainly involve literature research, analytical derivations, simulations and/or programming. However, design/experimental topics are also available.

Examples of available topics are:

- Power flow control in DC distribution grids
- Transient analysis of DC distribution grids
- Small-signal stability of DC distribution grids
- Centralized/Decentralized/Distributed control of DC distribution grids
- Optimal sizing and location of storage in DC distribution grids
- Stochastic analysis of uncertainty in DC distribution grids
- Protection of DC distribution grids

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  Prof. Dr. Eng. Pavol Bauer (P.Bauer@TUDelft.nl)
EXPERIMENTAL DESIGN AND VALIDATION OF DC DISTRIBUTION GRIDS

Type of project: MSc thesis

Scope: It is essential for the broad adoption of DC distribution grids to design an experimental set-up and verify the research done on the modelling, stability, control and management of DC distribution grids. Different projects are available to design converters or do experimental work.

Problem definition: Distribution grids are subjected to changes such as the increasing participation of distributed energy resources (DER), segmentation of the grid, and increasing participation of consumers and producers. This poses significant challenges with respect to stability and control. DC distribution grids are foreseen to have advantages over ac in terms of efficiency, distribution lines, and converters. However, more theoretical and experimental work is required to research and prove these advantages.

Methodology: These topics either mainly involve the design of suitable converters and/or the execution of experiments. Moreover these projects entail literature research, simulations and programming.

Examples of Research Objectives:

- Simulation of DC distribution systems
- Design of an isolated DC/DC converter
- Converter (PCB) design
- Programming power electronic converter’s microcontroller
- Design and implementation of the communication between power electronic converters
- Conduct experiments regarding the control of DC distribution grids

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GAN BASED POWER LINE COMMUNICATION FOR MORE INTENSIVE DATA TRANSMISSION

Type of project: MSc thesis

Problem definition: Nowadays, the concept of ‘smart house’ is becoming popular, where the controllability of all the electric loads is highly required. WiFi has already been used in some smart houses for communication. But WiFi can be easily hacked, and if that happens, breakers in the grid can be tripped by e.g. turning on all the electric loads simultaneously. Power line communication (PLC) can ensure higher cyber security of the grid. The problem of PLC is its relatively low bandwidth, and the bottleneck is the switching frequency of the converter.

Methodology:
- Literature review of the PLC technologies
- Identify the challenges in PLC technologies
- Evaluate the possibility of increasing bandwidth of PLC by using GaN

Research Objectives:
- Build GaN converter prototype which can do PLC
- Investigate the limitations of the PLC with the built prototype

Contact details:
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PLANNING ENERGY STORAGE IN MV DISTRIBUTION GRIDS: IMPLEMENTATION OF MODULAR CASCADED H-BRIDGE CONVERTERS AND ANCILLARY SERVICE PROVISION

Type of project: MSc thesis

Scope:
Study and implementation of modular power electronics and intelligent control algorithms to integrate energy storage into medium voltage (MV) power grids and provision of ancillary grid support.

Problem definition:
The penetration of intermittent renewable energy sources like wind and solar is dramatically increasing. At the same time introduction of new types of loads like electric vehicles is resulting in an increased and unpredicted demand of electricity. This has brought about severe impacts on electrical distribution networks, which currently offer very little operational flexibility. In the future, it is expected a substantial increase in the number of Battery Energy Storage Systems (BESSs) connected to the low voltage or medium voltage distribution networks. For the medium voltage grid modular power electronics based on the cascaded H-bridge converter (CHB) constitutes a good choice. Therein, the required isolation can be shifted to the modular cells where a high frequency AC-link is created. This circuit is not only well suited for congestion management but it can also work as a STATCOM providing harmonic compensation and other ancillary grid services.

Methodology:
To study and design a power converter implementing the CHB converter and LLC resonant circuit. Evaluate the benefit of using the energy storage system for several grid ancillary service provision.

Research Objectives:
- Literature review of BESSs in medium voltage grids and grid ancillary service provision market;
- Benchmark the proposed BESSs against state of art solutions;
- Implement the developed study in a hardware demonstrator.

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Planing the Future DC Grids in Smart Houses: Electric Vehicle Charger

Type of project: MSc thesis

Scope:
Study, design and implementation of isolated DC-DC converter for implementing DC-type charging of Electric Vehicles (EV) to be used in future smart houses implementing a DC grid.

Problem definition:
The Electric Vehicle (EV) charging market is very dynamic. In the future, more often DC-type chargers placed “off-board” with higher power capability will be employed than the currently intrinsic “on-board” AC-type chargers supplied by the car manufacturers. Additionally, home-type DC chargers with moderated power capability will be more often used when the houses become smarter. Therein, a DC-distribution grid will be available bringing a cost advantages for all DC-loads of the house, such as the EV batteries. Due to safety reasons the EV battery charger will be galvanically isolated from the public AC grid. This circuit will also demand for high power efficiency, low cost and to be able to deliver power to a wide range of battery voltages, i.e. 300 .. 1kV.

Methodology:
To study, simulate, design and test an isolated DC-DC converter for charging EVs using computational tools and TU Delft’s laboratory facilities.

Research Objectives:
- Literature review and proposal of suited power electronics circuits for DC-type EV chargers;
- Benchmark the proposed circuits;
- Simulate, design and construct an advantageous DC-type EV charger concept.

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# HIGH TEMPERATURE SUPERCONDUCTIVITY FOR DEGAUSSING

**Type of project:** MSc thesis

**Scope:**

Due to their permeability, naval ships distort Earth’s magnetic field. These anomalies in the magnetic field can be detected by sensors attached to airplanes or, even worse, magnetic mines. Luckily, there are methods to prevent detection by making ships “magnetically invisible”. One of these methods is to install a degaussing system, a set of coils designed to induce a magnetic field which compensates for the distortion.

**Problem definition:**

Nowadays, degaussing coils are made out of copper. Due to energy losses and weight issues, however, it might be better to use a superconductive material. Moreover, the developments in high temperature superconductivity (HTS), makes the use of superconductors a serious option.

In a degaussing system, multiple coils are used. Due to the magnetic coupling of these coils, noise from on-board power electronics, geometry of the ship and other reasons, a complex control system is required. It is expected that the implementation of superconductive coils has a significant impact on the control system.

**Methodology:**

In this project a model should be built to simulate the effect of the use of superconductive coils on the control system and to test control strategies. Laboratory experiments might be needed to verify the results.

**Research Objectives:**

- To conduct a literature review
- To obtain a model of superconductive coils and a degaussing control system
- To define and test an experimental test set-up

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#AGING OF HVDC TRANSFORMER’S INSULATION SYSTEM

Type of project: <MSc thesis>

Scope:
< To understand aging mechanism of oil-impregnated paper exposed to AC superimposed with DC and pulse stress.>

Problem definition:
<Converter transformer is an important part of a HVDC link. Any unexpected failure of such transformer can be very costly due to the cost of transformer itself and the cost of power interruption. Condition monitoring of such transformer is therefore very crucial. To be able to properly interpret partial discharge measurements recorded from a converter transformer it is necessary to understand how each dielectric component inside a converter transformer behave to different stresses. Paper insulation inside a converter transformer is stressed by DC and distorted AC electric field at the same time while on a conventional transformer the insulation is only stressed by AC electric field. Partial discharge behaviour of a converter transformer is therefore different than a conventional transformer and hence the interpretation is different.>

Methodology:
<The work is experimental based and should be carried out in high voltage laboratory. Lifetime of oil-impregnated paper insulation should be investigated under simultaneous DC and AC superimposed with pulse electric stress. Evaluation of PD over lifetime and change of impulse breakdown strength of oil-impregnated paper should be analysed.>

Research Objectives:
- < literature review of insulation system used in HCDC converter transformer and a summary of available tests used to ensure a proper made converter transformer>
- <Aging of oil-impregnated paper stressed with AC superimposed with pulses, as well as DC superimposed with pulses>
- <Measurement of Impulse breakdown strength and PD activity of electrically aged oil-impregnated paper>

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CONTROL SYSTEM FOR ELECTROSTATIC VOLTMETER

Type of project: <Extra project>

Scope:

The goal is to construct a control unit for electrostatic voltmeter to measure potential distribution along a surface. The device will then be used to measure surface charge decay over commonly used dielectrics.

Problem definition:

Surface charges may accumulate on the surface of DC insulator and alter electric field distribution. In gas insulated substations due to field emission from the enclosure, electric charges are injected to SF6 and deposits on the surface of the spacer. In outdoor polymeric insulator surface charges are formed on the insulator due to corona activity. The presence of surface charges may decrease the breakdown strength of the insulator, leading to failure of HVDC component (in the event of lightning impulses) and hence interrupting power transmission. Therefore understanding how surface charges form and decay on the surface of insulator is very important for HVDC insulation design. HV laboratory has recently bought an electrostatic voltmeter. The voltage probe must be mounted a 2 axis CNC unit to scan the surface potential at a fix distance between the probe and the plate. Proper rails, bearing and stepper motors, type of microcontroller, together with flexible control algorithm (speed of scan, initial point setting) must be purchased, programmed and constructed. The final product will be used to measure surface charge decay over commonly used dielectric materials.

Methodology:

Proper components for a 2 axis CNC control unit must be chosen and purchased. A code must be written to control the stepper motors with the required flexibility. Final product should be assembled and used to measure charge decay over known dielectric sample. The results of the measurement must be compared with literature.

Research Objectives:

• Purchasing the proper components for 2 axis CNC unit and development of the control code
• Assembling of the product and testing its performance by means of surface charge decay over known dielectric material and comparison with literature.
• Writing the final report and user manual for the developed device.

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FEASIBILITY STUDY OF TRANSFORMER NOISE MAPPING BY MEANS OF VIDEO/IMAGE PROCESSING

Type of project: <Extra project>

Scope:

In this project feasibility study of transformer noise mapping using video files and image processing techniques should be investigated.

Problem definition:

A video file captured of an object can reveal significant amount of information about that object. These information can be extracted if proper image processing technique is used. Recently it has been shown that vibration of overhead line conductor can be extracted using signal processing of captured video files from a vibrating conductor. Noise generated from a transformer can be used as a diagnostic tools to assess the performance of the transformer. High amount of acoustic noise can also be disturbing for the people living nearby a substation and hence requires action to reduce the noise level. Acoustic noise measurement and creation of a noise map for a transformer is therefore of interest. Conventionally this is done by means of microphone that are moved around the transformer and a colour map representing the magnitude of the noise with respect to the location of the noise is created. This kind of map can be used to interpreting the reason behind high amount of noise and possible active damping arrangement to suppress the disturbing acoustic noise in the environment. Acoustic noise generated by a transformer is equivalent to vibration of the transformer body. This vibration is different at different locations on the transformer tank. This subtle vibration can be extracted out of colour change of a video file taken from the transformer.

Methodology:

The work mostly involves MATLAB coding and video/image processing. An algorithm should be developed to extract tiny motion through colour change of images in a video files. Simple experimental setup with known noise sources will be used to test the developed algorithm.

Research Objectives:

- <literature review of available motion magnification techniques>
- <Development of a motion magnification algorithm suitable for extraction of tiny colour changes in an image and verification of the code through experiment>

Contact details:

- Supervisor: <Mohamad Ghaffarian Niasar, m.ghaffarianniasar@tudelft.nl>
MODELLING OF CHARGE DECAY IN HVDC CABLES

Type of project: <MSc thesis>

Scope:
<To develop a model that can demonstrate charge decay and recovery voltage phenomenon on HVDC cables>

Problem definition:
<Space charges can accumulate in DC cables and alter the electric field distribution in the cable. Space charge build up and decay depends on insulation parameters, temperature, and environment. Charge decay can happen very quick or can take many days. When voltage is removed from a DC cable, trapped space charges can remain in the insulation for a long time. A de-energized cable can therefore develop potential difference between conductor and the sheath due to the available space charges. This is important from the safety point of view as such electric potential can be lethal. In this project a finite element model and a circuit model will be develop to demonstrate how the potential decay occurs when the voltage is removed from the cable. The model must be validated by means of experiment.>

Methodology:
<The work consists of development of a numerical model that can simulate charge decay and voltage recovery phenomenon in HVDC cables. The work also involve experimental work which will be done in high voltage laboratory.>

Research Objectives:
- literature review of mechanism of charge decay and voltage recovery measurement as a diagnostic method>
- <Development of a FEM model in COMSOL Multiphysics that simulate charge decay in HVDC cable. Development of a circuit model that can represent voltage recovery phenomenon>
- <Comparison of the developed model with experiment>

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- Peter Vaessen P.T.M.Vaessen@tudelft.nl, Rob Ross, r.ross@tudelft.nl,
STUDY OF TRICHEL PULSES IN AIR

Type of project: < Extra Project>

Scope:
To numerically model negative corona (Trichel pulses) in air using COMSOL Multiphysics software and Matlab. The aim is to control solver’s step size during the whole simulation to minimize the simulation time.

Problem definition:
High electric field around sharp points can cause local breakdown of air known as corona discharge. If the polarity of applied voltage is negative and the dielectric medium has electronegative gas (such as oxygen) repetitive pulses of the same magnitude is usually observed during corona discharge. The goal of this project is to solve hydrodynamic equations of charged particles coupled with Poisson’s equation, to model the so called Trichel pulses in 2D-axis symmetric domain. Proper meshing, type of solver and step size taken by the solver are important parameters. In this extra project it is expected that the model is controlled from Matlab and proper algorithm is developed to control step size during the whole simulation in order to lower the simulation time.

Methodology:
The work is simulation based and can be performed on the high end computer available in HV laboratory. Experimental verification has to be done when a functional model is developed.

Research Objectives:
- literature review, getting use to the existing model (how is it made, boundary conditions, functionality and limitations)
- Implementing and controlling the existing COMSOL model by Matlab. Identifying the most suitable meshing strategy and controlling solver’s step size to obtain shorter simulation time

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  Rob Ross, r.ross@tudelft.nl, Peter Vaessen P.T.M.Vaessen@tudelft.nl
# DESIGN AND MODELLING OF FAST RISE TIME MARX GENERATOR

## Type of project: Extra Project

### Scope:

The scope of this project is to develop a finite element model and design a fast rise time Marx generator. Fast rise time pulse generator is used to test insulation materials under high pulsed voltages.

### Problem definition:

High voltage impulse generators are capable to generate impulse with a rise time of 1.2 µs (See figure above). This impulse generators are useful to full fill the power system standardized tests. However, in recent years, by introducing power electronics converters, the shape and rise time of the pulses is going to change. To test insulation materials under faster rise time than standard lightning impulse generator, reconsidering the pulse generator and design of the pulse generator is needed.

### Methodology:

The work is mostly focused on the detailed design of fast rise time Marx pulse generator on computer simulation. After the development of the model, a prototype has to build to verify the accuracy of the constructed model and design procedure. The experimental part will be done in a high voltage laboratory of TU Delft.

### Research Objectives:

- A literature review of existing Marx generator and their design
- To be able to couple different physics in COMSOL Multiphysics software
- Development of a FEM model that can accurately predict the electrical parameter of the pulse generator
- Experimental verification of the constructed model

### Contact details:

- Babak Gholizad, B.Gholizad@tudelft.nl
DESIGN OF HIGH VOLTAGE SUPERCONDUCTING TRANSFORMER

**Type of project:** Extra Project/ MSc Thesis

![Superconducting transformer (left) and copper transformer (right) with comparable nominal power (medium voltage traction transformer)](source: M. Noe, EUCAS Short Course: Superconducting transformer)

**Scope:** The scope of this project is to develop a finite element (FEM) model and design a high voltage superconducting transformer.

**Problem definition:**

Superconductors are materials that can conduct a stationary electrical current without resistance. Higher current carrying capability of the superconductors provide a great opportunity to reduce the size of the power components. The size and weight of the component become an important factor in dense areas. Physics and working temperature of the superconducting materials are different. Modelling the physics and behaviour of the material require good understanding. Several numerical approaches to model the superconducting material has been developed. Applying those numerical approaches to design a component is the goal of this project.

**Methodology:**

The work is mostly focused on modelling and preliminary design of high voltage superconducting transformers. Analytical design and FEM design of the transformer to predict the losses and size of the transformer is expected.

**Research Objectives:**

- Literature review
- To be able to couple different physics in COMSOL Multiphysics software and build a physics of superconductor
- Development of a FEM model that can accurately predict the electrical parameter of the transformer
- Comparison between FEM and analytical design of the transformer

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DESIGN OF A COAXIAL SAMPLE FOR CALIBRATION AND CHARACTERIZATION OF SPACE CHARGE ACOUSTIC MEASUREMENTS

Type of project: MSc thesis

Scope:
Design of a sample resembling a full size HVDC cable, capable of emulating trapped electric charges at different radius of the cable’s dielectric bulk. The calibrated sample should be compatible with the acoustic methods used at Space Charge measurements.

Problem definition:
HVDC networks are widely increasing their presence in the transmission network due to the new developments and achievements of HVDC power converters. Therefore, measurement of the Space Charge phenomena in HVDC components is becoming more relevant. The availability of different space charge measurement methods brings the necessity of calibration and characterization of measurement equipment in order to reach standardized measurements. This brings the necessity of a reliable calibrated sample to reproduce the same charge values in different tests and equipment.

Methodology:
The research involves full understanding of the acoustic methods for space charge measurements. The student will make a design of the coaxial calibration sample and proceed to its construction and validation tests.

Research Objectives:
- Develop a design for a space charge calibration sample.
- Construction and testing of the sample prototype.

Contact details:
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- Supervisor: Armando Rodrigo Mor, A.RodrigoMor@tudelt.nl
INTEGRATED ULTRASOUND SENSOR FOR THE CALIBRATION OF PRESSURE WAVE PROPAGATION METHODS IN SPACE CHARGE MEASUREMENTS OF HV CABLES

Type of project: MSc thesis

Scope:
Design a electroacoustic sensor that will be coupled to a HV cable sample during PWP measurements. The use of this sensor should be capable of predict the measured space charge values at different trapped charge values.

Problem definition:
HVDC networks are widely increasing their presence in the transmission network due to the new developments and achievements of HVDC power converters. Therefore, measurement of the Space Charge phenomena in HVDC components is becoming more relevant. One of the challenges involving the measurement of SC in HVDC cables is the need of a HV at the inner conductor for calibration purposes; which brings the necessity of very long cables for the construction of terminations, as well as the incapacity of measuring SC in post-mortem tests. The capacity to measure the propagating pressure wave at different points of the cable allows to calibrate without the HV at the inner electrode.

Methodology:
The research involves full understanding of the PWP method for space charge measurements. Selection of the most appropriate sensor according to the electrical and mechanical requirements. The process involves simulations and extensive laboratory work.

Research Objectives:
- Selection and design of the sensor.
- Validation of the design by laboratory testing.
- Methodology to calibrate PWP method with the measured pressure waves.

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200 KV CLASS WIRELESS POWER TRANSFER ARRAY

Type of project: <MSc thesis>

Scope:
<The goal of this project is to design a wireless power transfer array with 200 kV insulation level capable of transferring 500 W per cell.>

Problem definition:
<High frequency pulses and harmonics are the type of stress that are being added to the grid following the increase penetration of power electronics. To ensure reliability of power component it is necessary to test them under actual stress present in the grid. It is therefore requested by number of testing companies, to design and prototype a high voltage arbitrary voltage waveform test generator. The goal of the project is to design a power electronics based HV test generator capable of generating 200 kV arbitrary voltage waveform. One candidate topology for such test generator is cascaded H-bridge topology. Isolated power supply is required in cascaded H-bridge topology with insulation clearance sufficient for the operating voltage of the test generator. Using ferrite core/iron core transformers at 200 kV insulation level requires a complicated insulation system which ends up into a bulky structure. In this regard, a novel idea of using wireless power transfer with high voltage insulation clearances is being proposed for this master thesis. The goal is to use existing knowledge in wireless power transfer, in combination with high voltage consideration required for this project, and come up with the most suitable design.>

Methodology:
<Existing designs for wireless power transfer will be reviewed first. The best transfer ratio that results in the most compact design, with suitable insulation clearances must be chosen. At least two cells should be built and tested. Mutual interaction between the cells, and insulation performance of the array must be analysed with experiments.>

Research Objectives:
- <Literature review of existing topologies for wireless power transfer>
- <Design and construction of the power array based on HV requirements and desired power transfer capability. Suitable dielectric and cooling system must be chosen>
- <Experimental verification of the concept design with at least two cells>...

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DYNAMIC CURRENT RATING MODEL FOR HVAC AND HVDC CABLES

Type of project: < Master project>

Scope:
<To develop a model for dynamic rating of HVDC cables taking into account electric field dependency of the insulation loss and field distribution.>

Problem definition:
<Dynamic rating is to better use the capacity of cable system without exposing it to risk of overheating and consequence lifetime reduction. In the cable course students learn how to evaluate cable ampacity, taking into account different losses and thermal model of the cable system at 50 HZ AC for a constant current. In this project the existing FEM models must be rebuild using MATLAB-COMSOL interface and controlled such that dynamic rating of power cables is possible. Field dependency of dielectric loss and temperature dependency of field distribution must be taken into account at the same time. This is to avoid over stressing HVDC cable insulation above the rated stress. An easy to use software must be developed for cable ampacity calculation.>

Methodology:
<The work is simulation based and is performed using COMSOL Multiphysics. Experimental setup consisting of current varying heating element immersed under water will be made to verify the accuracy of the model developed>  

Research Objectives:

- <literature review, to learn standard method for cable ampacity calculation>
- <development of a Matlab controlled COMSOL model for dynamic cable rating >
- <construction of experimental setup and verification of the developed model>

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MODELLING OF A FAST ACTUATOR FOR HVDC BREAKER APPLICATION

Type of project: <MSc thesis>

Scope:
< Development of a FEM model that accurately represent operation of a Thomson coil.>

Problem definition:
< To interrupt HVDC current three main technologies are available. In the first technology power electronic switches are used to interrupt the current. This technology offers a very fast operation (~1μs) however the on-state loss is rather high which makes the technology expensive to operate. The second technology is purely mechanical. The on-state loss for this technology is minimized but the operation time of the switch is rather high (~60ms). In the third technology a combination of both methods are used in which the on-state operation has almost a minimal loss while the operation time is reduced significantly (~5ms) compared to purely mechanical switch. To achieve an ultra-fast actuation a Thomson coil can be used. The coil is connected to a capacitor bank and the armature is connected to the breaker push-pull rod. By discharging the capacitor bank through the coil, the armature experienced a force which moves it away from the coil. The phenomenon involves number of physics that are coupled. Electromagnetism, heat transfer, Newton motion laws, and solid state mechanic equations. The involved physics must be solved together in order to accurately model the behaviour of the actuator.>

Methodology:
< The work is mostly focused on computer simulation. After development of the model, a small scale Thomson coil has to build to verify accuracy of the constructed model. The experimental part will be done in high voltage laboratory of TU Delft.>

Research Objectives:
- <literature review of the existing HVDC circuit breaker mechanisms and understanding operation cycle of each method>
- <To be able to couple different physics in COMSOL Multiphysics software>
- <Development of a FEM model that can accurately predict the operation of a Thomson coil>
- <experimental verification of the constructed model on a small scale Thomson coil>

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THERMAL MODELLING OF OIL IMMERSED POWER CONVERTERS

Type of project: <MSc thesis>

Scope:
The goal of this project is to develop a CFD model to accurately predict temperature distribution and hotspot location of oil immersed power converter.

Problem definition:
DNVGL in cooperation with DCE&S group aims to build a power electronic based high voltage arbitrary waveform test generator. The ultimate goal is to immerse this test generator under oil in order to reduce the size of the device. This is important since the test generator can be used for mobile testing purposes. To understand heat dissipation and temperature distribution in the device, it is necessary to create a full 3D thermal model of the device. The governing equations are Naiver-Stokes equation and continuity equation. Heat source are the power dissipated by the power transformers as well as power switches. The simulation is based on finite element method and COMSOL Multiphysics is used as simulation software.

Methodology:
In the first stage a 2D-axis symmetric design of a transformer winding will be developed. This is to get use to fluid dynamic modelling and to avoid convergence issues of 3D models in the initial stage. The results of this part must be verified with experiment. Following the development of the first stage, a 3D model for oil bath together with blocks of heat sources placed in the oil bath will be developed.

Research Objectives:
- Literature review of CFD modelling of oil-filled transformer
- Learning how to set up CFD model in COMSOL Multiphysics and working with existing fluid dynamics model
- Developing 2D-axis symmetric model for transformer winding, considering different boundary conditions for oil inlet and outlet. Verification of the model with experiment
- Developing of 3D CFD model of oil bath with blocks of heat sources, computing temperature distribution and oil velocity in various locations of the system.

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