DC Systems, Energy conversion & Storage
Matchmaking Event
April 2017
ANALYSIS OF ACTIVE CONTROL METHODS TO IMPROVE CONVERTER RELIABILITY IN WIND TURBINES

Type of project: MSc thesis

Scope: The project explores the control of electrical parameters to improve lifetime performance of converters for wind turbine generator systems.

Problem definition: Power Electronic Converters have a high failure rate and are a bottleneck in the reliability of generator systems. There is existing literature that proposes the increasing of lifetime by control that considers change in load current, sharing power between parallel devices and the modification of loss distribution. Other proposals include controlling the modulation strategy along with the control of switching frequency. This project aims to analyse and compare these possibilities by modelling their effects on the lifetime of a 10MW wind turbine drivetrain.

Research Objectives:

- Create an inventory of electrical parameter based control methods to improve lifetime.
- Model these control methods in a 10MW PM Direct Drive drivetrain.
- Analyse and compare the performance of these methods.

Collaboration with Industry: No

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HOT SWAP SOLUTIONS FOR WIND TURBINES

**Type of project:** MSc Thesis

**Source:** [http://new.abb.com/power-converters-inverters/wind-turbines](http://new.abb.com/power-converters-inverters/wind-turbines)

**Scope:** The study is constrained on qualitative analysis of hot swapping technologies for modular converters in wind turbines. In the final stage of this thesis one of the proposed concept will be implemented in the DCE&S laboratory.

**Problem definition:** Modularity is pursued to minimize the down-time and increase the availability of wind turbine systems. The core of high availability is redundancy (coming from modular design) and/or multi-functionality (in case of failure one substitutes the failed one). Modular design relies on scalability, configurability and pluggability. In this thesis the latter will be studied. This involves a detailed study of how faulty modules can be bypassed in a wind turbine, and the influence of failure types on the bypass solution and sensor requirements.

**Methodology:** The thesis starts with literature study of the hot swap solutions and failure types in the PM wind turbine drivetrain. Based on the literature study the concepts will be modelled in Matlab-Simulink and evaluated. Most promising design will be implemented and a proof of concept created.

**Research Objectives:**

- Analysis of bypass solutions for modular converters in PM wind turbine on generator and grid side.
- Analysis of failure types in wind turbines and their influence on bypassing solutions and sensor network.
- Analysis of scalability.
- Proof of concept.

**Collaboration with Industry:** No

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**Type of project:** MSc thesis/ Extra Project/ SIP 2

**Scope:** This project explores the use of nanofluid coolants to improve cooling performance of heat sinks for power electronics.

**Problem definition:** The cooling circuit is an important part of the power converter and influences not only the size of the converter but also its reliability. The use of nanofluids for cooling gives rise to new opportunities for improving cooling performance. This project is one step in this direction. The main objective is a design of a testbed for comparing the thermal performance of the nanofluids with conventional cooling methods used in power electronic converters. After successful design of the testbed and creation of a test procedure, the student will execute the testing in cooperation with the Synext R&D team.

**Methodology:** The project includes designing and running an experimental setup followed by an analysis of the results. The proposed methodology is,

- Short literature survey to find existing theoretical and empirical basis.
- Formulate the problem.
- Design and assemble the testbed.
- Perform cooling tests with different coolants.
- Analyse and interpret results.

**Research Objectives:**

- Design and assembly of a cooling testbed.
- Development of Testing Procedure and Scenarios.
- Data acquisition and interpretation.

**Collaboration with Industry:** Yes – Synext R&D

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OPTIMUM PHASE SHIFT IN INTERLEAVED PFC CIRCUITS

Type of project: MSc thesis

For high power factor correction circuits (PFC) the EMI filter becomes very large. One of the proposed remedies for that is to interleave two PFCs. Then only the resulting current has to be filtered. In literature 180° phase shift is generally assumed. However: it might be questionable whether this is the right choice taken the required EMI filter into account.

Scope: To develop an optimal interleaving strategy for BCM interleaved PFC stages as function of frequency.

Problem definition: A complicating factor is that a practical BCM PFC has also an idle time during which the drains voltage rings to a minimum. This idle time varies with switching frequency of the PFC converter. New semiconductor technologies promise to enable MHz switching frequency. This in itself leads to smaller passive components in the boost converter (used as PFC) itself, however: The higher the switching frequency, the larger the influence of this ringing on the total switching cycle. Has that a large impact? And what will be the optimal phase shift between the two PFC circuits become? How much will the optimal phase shift reduce the required EMI filter compared to the “standard” 180° phase shift

Methodology:
1. study the behaviour of interleaved BCM PFC circuits as used in practice
2. simulated the interleaved PFC in a simulator e.g. LTSpice or any suitable simulator
3. do the mathematical analysis to match simulation and calculations
4. measurements of EMI for a single boost converter with varying ringing time
5. if time permits: do the same for an interleaved BCM PFC (NB: control circuits are available on the market)

Research Objectives:
- Interference model for the interleaved stages, simulations & mathematical proof.
- Idem for idle time between switching cycles (with idle time as a variable)
- NB: potentially a paper could result

Collaboration with Industry: No.

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MOBILE SMART CHARGER WITH GAN SWITCHES, RUNNING AT > 1 MHz

Type of project: MSc thesis

Feasibility study for a 25-65W mains isolated flyback for smart charging of mobile applications, wherein for size & loss reduction the traditional Si-MOSFETs are replaced by GaN switches, and a switching frequency of > 1 MHz. If time permits also investigations into improved transformers for very high frequency is preferred.

Scope: Reduction of size and losses in a charger for mobile applications saves energy and raw materials. For size reduction a high switching frequency is a must.

Problem definition: There is ongoing request for reduction of waste energy and reduction of size of chargers for mobile applications. Also from an environmental point of view this is highly preferable. One of the key issues for this is switching at very high frequency. Previous studies n size, which include mandatory EMI filter, have shown that in order to achieve this the switching frequency must be around or – preferably - well above 1 MHz. Present day Si MOSFETs have only limited capabilities to switch at > 1 Mhz. GaN switches promise to overcome this limitations, as they have low on-resistance, low capacitances, easy drive and fast switching. Before proposing this to the market a feasibility study must be carried out to verify whether the new switches indeed live up to their promises. Also a look into another key component: the transformer, might well be included.

Methodology:
1. study the behaviour of the normal operation of a flyback converter as used for chargers
2. make a rough model for the losses n the GaN switch to verify optimal frequency setting
3. design a flyback converter for 1 MHz, incl. the transformer and the mains filter for CM noise
4. build the converter
5. measuring efficiency etc. and verify EMC behaviour

Research Objectives:
- study hf switching with GaN in a mains isolated flyback (not yet shown n literature!)
- investigation of influence of parasitics in this type of converters

Collaboration with Industry: Yes. The study is preferably done at the NXP premises in Nijmegen, in an expert-group on flyback converters.

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SUPPORTING DIGITAL DESIGN OF NEXT GENERATION USB-PD CONTROLLERS

Type of project: MSc thesis

USB power delivery will soon become a main stream type of powering various devices. To enable this in a power efficient way, and at low cost and size, smart controllers have to be developed. Next generation USB-PD controllers will be mixed signal ICs, with increasing digital content, supporting multiple protocols.

Scope: Improvement of digital controllers for USB-PD, focussing on the support for optimising the design of this control circuitry in various aspects, and adopting state of the art.

Problem definition: There is ongoing request for reduction of waste energy and reduction of size of power supplies for various applications. Also the cabling is an issue as it is not cost effective and consumes raw materials. USB-PD is one of the means to solve this. For the control of the power delivery using the USB cable standards have been developed (and are still being improved). Quite some digital signals are involved. Therefore a digital controller is the obvious way to go. As the control strategies are still in the infancy, quite a lot of improvement should be possible.

Methodology:
1. study the standards for USB-PD
2. improving in a team the existing proposals for control
3. verifying and testing the (overall) performance. Involving and improving the methodologies mandatory for guaranteeing competitiveness and quality

Research Objectives: Investigations in advancing control algorithms

Collaboration with Industry: Yes. The study is to be done at the NXP premises in Nijmegen, in an expert-group on flyback and resonant and similar converters

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**Resonant Converter with GaN Switches (100 - 300W)**

**Type of project:** MSc thesis

Feasibility study and demo project for a 100 – 300W mains isolated resonant converter, wherein for size & loss reduction the traditional Si-MOSFETs are replaced by GaN switches, and a high switching frequency. There is already a controller for a very high efficient resonant power supply, but further improvement is still highly wanted.

**Scope:** Reduction of size and losses in a power supply saves energy and raw materials. For size reduction a high switching frequency is a must.

**Problem definition:** There is ongoing request for reduction of waste energy and reduction of size of power supplies for various applications. Also from an environmental point of view this is highly preferable. One of the key issues for this is switching at very high frequency. Present day Si MOSFETs have only limited capabilities to switch at high frequency. GaN switches promise to overcome this limitations, as they have low on-resistance, low capacitances, easy drive and fast switching. Before proposing this to the market a feasibility study must be carried out to verify whether the new switches indeed live up to their promises.

**Methodology:**
1. study the behaviour of the normal operation of a resonant converter.
2. make a rough model for the losses in the GaN switch to verify optimal frequency setting
3. design a resonant converter for 1 MHz, incl. the mains filter for CM noise
4. build the converter
5. measuring efficiency etc. and verify EMC behaviour

**Research Objectives:**
- study hf switching with GaN in a mains isolated resonant converter
- investigation of influence of parasitics in this type of converters
- verify optimal usage of GaN switches

**Collaboration with Industry:** Yes. The study is preferably done at the NXP premises in Nijmegen, in an expert-group on world class flyback and especially also world class resonant converters

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REPLACEMENT OF OPTOCOUPLER BY RF COMMUNICATION THROUGH TRANSFORMER

Type of project: MSc thesis

In mains isolated converters most often the control information is transferred by means of an optocoupler. Can this be replaced by a rf signal using the existing transformer?

Scope: In a mains isolated flyback converter reducing component count and increasing efficiency simultaneously. The numbers of chargers etc for mobile equipment is huge. Any reduction of power consumption and component count help reducing pollution, and reduces the consumption of raw materials.

Problem definition: In most isolated converters the control info is transferred from secondary side to primary side using an optocoupler. This coupler consumes energy, and adds to cost. The questions arises: can the transfer of information be done with components that needs to be used anyhow, esp. the transformer. A transformer can be used for transferring power, but also for transferring information. Can this be done with the same transformer? A potential candidate is to use an rf signal to be coupled to the transformer to do this. The bandwidth of the communication must be large enough and the communication should be bidirectional, paving the way for more sophisticated features.

Methodology:
1. study the behaviour of the normal operation of a flyback converter as used for chargers
2. study the possibility of transferring power and hf information using the same transformer, including constraints on frequency span, sensitivity for noise, etc.
3. proposal for the way the information is transferred by means of a hf signal (e.g.: pulses (with protocol), fm modulation, etc.)
4. building prototype, and assessing feasibility (efficiency, performance, cost etc.)

Research Objectives:
- knowledge on multi-purpose use of transformers for power supplies
- knowledge on interaction of hf signals and switched mode power transfer in transformers
- optimisation of efficiency and size of power supplies with mains isolation

Collaboration with Industry: Yes. The study is preferably done at the NXP premises in Nijmegen, in an expert-group on flyback converters

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VERILOG AMS MODELS FOR POWER SUPPLIES

Type of project: MSc thesis

The modelling of power supplies is still not mature. In order to better predict performance in various aspects improved description of system level behaviour must be developed, including the components.

Scope: Better models will lead in the end to better power supplies. This will lead not only to better performance, but also to size and cost reduction, and to lower waste energy.

Problem definition: There is ongoing request for reduction of waste energy and reduction of size of power supplies for various applications Also from an environmental point of view this is highly preferable. Though quite some knowledge exists on how to achieve this, it is still not possible to model the overall performance on all relevant aspects on beforehand. For optimizing the power supplies this is highly preferable. Verilog AMS is a promising candidate to make a significant improvement.

Methodology:
1. study the behaviour of the normal operation of relevant converters (main candidates: flyback and LLC resonant).
2. Make a description of a chosen power supply, which includes the relevant aspects for developing.
3. Verify the AMS model in an existing power supply, by simulation and measurement.

Research Objectives: To build a good model to improve predictability, Note: >15 different components contribute to the losses in a power supply.

Collaboration with Industry: Yes. The study is to be done at the NXP premises in Nijmegen, in an expert-group on flyback and resonant converters

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**DESIGN OF SWITCHED BOOST INVERTER (SBI) FOR DC NANOGRID APPLICATIONS**

**Type of project:** MSc thesis

![Switched boost inverter](image)

**Figure[1]: Switched boost inverter a) Circuit b) Application**

**Scope:** SBI is a single-stage power converter that can supply both dc and ac loads simultaneously from a single dc input (see Figure 1). So, it can realize both the dc-to-dc converter for solar panel and the dc-to-ac converter in a single stage. This decreases size and cost of the overall system, thus holding a huge potential for applications in future dc Nanogrids.

**Problem definition:** Future dc nanogrids like households, data centres are all moving towards a dc distribution system leading to reduced number of reduced stages (AC-DC) leading to higher efficiencies. However, this leads to higher number of load dedicated converters thus increasing the need for communication and reducing reliability. That’s why research in single-input, multiple-output (SIMO) converters or even multiple input multiple output (MIMO) converters is important to solve these aforementioned challenges to make dc Nanogrids more attractive.

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

- Extensive literature review on SIMO and MIMO converters
- Steady state modelling and PWM control strategy selection - Loss modelling and heatsink selection
- Hardware implementation and proof of concept

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

- Applicability of SBI in dc nanogrid applications
- Suitable Control algorithms for SBI inverters
- Comparison with already existing topologies in terms of efficiency, reliability and Bill of material

**Collaboration with Industry:** No

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MULTI-FREQUENCY ACTIVE FILTERING

**Type of project:** MSc thesis

**Scope:** Design, build and test a modular series and/or parallel active filter for operation in multi-frequency micro-grids. This converter will be assembled with pre-existing component submodules equipped with sufficient sensors and control capabilities. The appropriate control strategy needs to be chosen and then tested under various conditions.

**Problem definition:** As part of a novel Multi-frequency micro-grid, the inclusion of a certain components that provide an enhanced power quality is an important feature. Active filters are common-place in various AC and DC systems and applications. However, the presence of additional (superposed ) frequencies provides a new layer of control that needs to be addressed. The physical filtering module (composed from pre-existing submodules )may require only certain modifications. The main goal is to put forward and test a control strategy that can actively track and mitigate various harmonics present in the system via the available sensors and control devices.

**Methodology:** In order to achieve active filtering under these conditions, certain steps should be followed. This includes proposing a control strategy based on the available voltage and current measurements. Afterwards, the control strategy should be tested via a simulations on a Matlab model of the system. Finally, the active filter should be assembled, tested and evaluated on a laboratory setup.

**Research Objectives:**
- Identify the requirements of MF active filtering.
- Propose a control strategy for the MF Active Filter.
- Test and evaluate the MF Active Filter via simulation and laboratory experimentation.

**Collaboration with Industry:** No

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MULTI-FREQUENCY POWER MEASUREMENT BOARD

Type of project: MSc thesis

Scope: Design, assemble and test a PCB board capable of high-precision measurements of electrical power flow on various frequencies (including DC) in a MF micro-grid. By incorporating various sensors and available controllers, a multi-port device should be assembled and programmed to track the power flow on individual frequencies going through it.

Problem definition: In a novel Multilevel, Multi-frequency power systems that is currently being designed, measurement of power flow is more challenging. This is due to the presence of at least one or more AC frequencies that are superposed on a DC offset. Power tracking of multiple frequencies can be achieved by a measurement board containing the proper voltage/current sensors, conditioning circuits and available controllers. Along with the necessary choice of hardware, the proper algorithms need to be incorporated within the controller.

Methodology: Firstly a method of isolating and calculating the relevant parameters within the limits of the available controllers needs to be suggested. This method should then be tested and verified via simulations on a model MF system. Afterwards, the process of designing the actual prototype board can begin along with the programming of the controller. Finally, the Measurement Board should be tested on a laboratory setup of the system.

Research Objectives:

- Propose a MF power measuring method.
- Design a device to accommodate the required components.
- Test the measuring accuracy of the program via simulation and experimentation.

Collaboration with Industry: No

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Type of project: Extra Project

Scope: Implementing existing power electronics submodules to design, assemble and test various common converter topologies. These include conventional isolated and non-isolated DC/DC and DC/AC converters.

Problem definition: An ideal opportunity for any student that wishes to get hand-on experience with operating various topologies of widely implemented PE converters. With existing PE “building blocks” (sub-modules) with pre-installed switches, sensors and control components a wide assortment of converters can be assembled. Using standard testing practices, these converters need to be tested under various loads and/or source conditions. A performance analysis should be presented as part of the final report.

Methodology: Firstly, the student needs to get acquainted with the operating principles of the individual submodules. After this, a number of possible converter topologies should be suggested along with their control principle. Finally, adjusting the controller, followed by various experiments under certain conditions will be carried out in order to demonstrate the PE Building Blocks performance.

Research Objectives:

- Identify possible converter topologies.
- Experiment with different combinations of PE building blocks.
- Test and analyse the performance of the submodules for different topologies.

Collaboration with Industry: No

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BATTERY EMULATOR FOR TESTING PE INTERFACE MODULES

Type of project: MSc thesis

Scope: Design a laboratory setup that can replicate the behaviour of an electrical battery storage unit. Assemble, program and test the emulator under power electronic (PE) interface conditions.

Problem definition: With the growing interest in nano-grids and a wider utilisation of energy storage units, the accompanying PE converters that are required to interface and control the power flow need a platform on which they can be tested. Actual high-power batteries are hazardous to experiments with, while off-the-shelf emulators are costly and can function in a limited range. The solution therefore is to custom design converters that can be programmed to behave as a battery under both charging and discharging conditions. By implementing a topology similar to the one in the figure, a wide range of conditions can be achieved by combining various switches, resistors and quantity of commercially available safer-batteries or power sources. The task is therefore to design, assemble and program such a setup for laboratory implementation.

Methodology: Assemble a converter based on the layout given in the figure. Choose the appropriate components and design its PCB board. Program the available controllers to operate the switches in the device. Test the battery emulator via simulations on a system model and finally laboratory experimentation on the setup.

Research Objectives:

- Identify the key features of a battery emulators.
- Design and assemble the emulator based on these features.
- Test the operations of this converter via simulation and experimentation.

Collaboration with Industry: No

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COMPARISON OF VARIOUS PE MODULE CONTROL STRATEGIES

Type of project: MSc thesis

Scope: Based on the available sensors and computational power located on existing power electronic (PE) building blocks, the goal is to compare and evaluate different control strategies that can be applied. This application will depend on the choice of the various sensors that are available and the processing power of the controllers that are on hand.

Problem definition: The control of PE converters are usually one of compromise. High-performance devices require an adequate number of precis measuring components and/or a sufficiently capable controller. By experimenting with different control strategies and utilising various combinations of sensors, one can analyse and compare the performance of the converters under certain steady-state or transient conditions. This could allow for more rapid prototyping in future designs as the trade-off between component count/cost and performance will be better known.

Methodology: After analysing the available hardware components and potential of the controllers, several control strategies should be put forth. Programming and running the simulation of the model setup, followed by experimentation and analysis of the controller performance should shed light on the benefits and limitations of these strategies.

Research Objectives:

- Research the various converter control principles and there requirements.
- Examine as much of these control strategies within the hardware and processing limitations.
- Analyse and compare the performance of these module control strategies.

Collaboration with Industry: No

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**Master’s Thesis Proposal**

**DESIGN AND EVALUATION OF SIC SWITCHING SUBMODULE**

**Type of project:** MSc thesis

**Scope:** Using available SiC MOSFET switches and high-frequency drivers, the goal is to design a high-performance half-bridge submodule (SM) for use in “building block” design application. This SM should also include various sensors, snubbers and communication ports in order to properly function as part of a broader system.

**Problem definition:** SiC and other wide band-gap devices are still relatively novel in terms of applications. Due to their high performance potential, SiC switches could be pushed to high-frequency operation. This is ideal in some aspects but creates problems in various other domains such as EMI and stress on other components of the converter. Therefore a proper design is required for modules implementing SiC MOSFETS. This needs to take into account both the layout and choice of adjacent components. Final incorporation, testing and evaluation of the SiC switching SM in actual converter topologies (DC/DC, DC/AC) will be carried out.

**Methodology:** The utilisation of SiC MOSFET switches on a submodule level requires experimentation with different layouts and design approaches in order to achieve an optimal solution. Several iterations may be necessary before an acceptable result can be achieved. Simulations and experiments in laboratory setups will be used in the design phase and final evaluation.

**Research Objectives:**

- Identify the potential benefits and challenges of implementing SiC MOSFET switches.
- Design a half-bridge SM that mitigates most of the challenges.
- Analyse and evaluate the performance of these submodules.

**Collaboration with Industry:** No

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DUAL ACTIVE BRIDGE MODULE FOR MULTILEVEL APPLICATIONS

Type of project: MSc thesis

Scope: Modify a DAB converter to operate as a module in a Multilevel system. By reconfiguring certain elements on an existing prototype, the module should be able to communicate with other modules while interfacing certain loads/sources.

Problem definition: Conventional MMC and other Multilevel systems usually implement modules that do not provide galvanic isolations between their input and output. By modifying existing DAB converters we can reconfigure them to operate as modules as part of a broader system. The inclusion of certain sensors and communication ports may also be necessary to achieve access to control parameters and compatibility with other modules. Reprogramming the DAB converter to function as a module will also be required. Simulation on a system model and finally experimentation on a laboratory setup will serve as a testing platform and validation of the expected converter performance.

Methodology: The methodology for this thesis will include getting familiar with the layout and design of the existing DAB converters. Afterward a reconfiguration process by adding or removing certain elements will be required. Adjusting the controls for multilevel operations and testing them via simulations should precede the final experimental verification of the module.

Research Objectives:

- Analyse the design and operational principle of DAB converters.
- Reconfigure existing DAB converter to operate as an isolated module in a Multilevel system.
- Test and analyse the performance of this module via simulation and experimentation on a laboratory setup.

Collaboration with Industry: No

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**Type of project:** Extra Project

**Scope:** Based on the available converters that replicate the power curves of PV cells, the goal is to redesign them in order to achieve a higher power rating and possibly a more accurate performance.

**Problem definition:** There are various methods of extracting data from systems that incorporate PV sources. However, in laboratory environments, where available space is usually limited, any setup needs to be compact and highly robust. Therefore, by implementing the tools and equipment that are at hand, the task will be to modify an existing PV emulator for the purpose of testing other converters intended to interface PV sources. These emulators function by operating the switch in the linear (active) region while being supplied by a conventional DC power source. In order to scale up the power rating of the emulator, the student should reconfigure and possibly reprogram the converter by choosing the proper components and adjusting the controls to suit their switching needs. Simulations and experimentations should be carried out during the design process.

**Methodology:** After getting familiar with the basic design and operating principle of the existing emulator, a process of redesign should follow. This process includes choosing which elements to preplace and adjusting the controller to suit them. Assembly, simulation and experimental testing can than take place.

**Research Objectives:**

- Identify key feature of the PV emulator.
- Reconfigure the emulator and modify the controls to suit a high power rating.
- Test the operations of the converter.

**Collaboration with Industry:** No

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GLOBAL ENERGY REQUIREMENT (GER) COMPARISON OF MODULAR AND CONVENTIONAL POWER ELECTRONIC CONVERTER

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

Scope: Compare primary energy consumption over the entire life cycle of a Single Flyback (or Forward) converter and Interleaved Flyback (or Forward) converters.

Problem definition: Power electronic converters are the cornerstone of smart home and smart grids. Due to the large variety of power electronic solutions required in these applications, modular architectures are being re-investigated. However, only such solutions are truly sustainable that save more energy than they consume over the complete life cycle. This SIP project is one of the first steps towards building a comprehensive understanding of sustainable design of modular power electronic converters.

Methodology: The first step is the design of two converters for a smart DC house. On the bill of materials from the design stage, a life cycle analysis will be performed. Total primary energy consumption over the entire life cycle for both converters will be calculated. The project will finalize with a comparison of total GER and comparison of primary energy consumptions in different life stages.

Research Objectives:
- Design Single Flyback and Interleaved Flyback converters
- Perform Life Cycle Analysis
- Calculate Global Energy Requirement

Collaboration with Industry: No

Contact details:
- PhD student: P. Purgat (p.purgat@tudelft.nl)
- Supervisor: P. Bauer (p.bauer@tudelft.nl)
PARALLELING SIC MOSFETS FOR LVDC

Type of project: MSc thesis

Scope: The low voltage DC distribution requires very efficient energy conversion devices, however due to the low voltage the currents are significant. Therefore, to reduce the losses in the active components parallelization is necessary. Unfortunately, the device parallelization is hindered by the mismatches inside the device and in the gating circuit. It is known how to parallel Si Mosfets but due to the difference for example in $G_{ds}$, the parallelization of SiC Mosfets will show different optimum.

Problem definition: The remedy for the mismatches can be found in an adjustment of the gating circuit of the MOSFETs. Increasing the gate resistance slows down the switching speed, thus reduces the dynamic mismatches at the turn-on. The adverse effect is slowing down the turn-off and a higher losses at the turn-off. Therefore, there is a trade-off and a limit to how many Mosfets can be paralleled, to a point where switching losses outweigh the conduction losses. Naturally, the ratio of the switching and conduction losses are heavily dependent on the switching speed.

Methodology: In the first phase of the project the student acquaints himself with the SiC Mosfet characteristics. In the second stage the relationships between the device and the gating circuit parameters are described. In the third stage, using the optimization tools an optimal solution is found and limits for the parallelization are drawn. The project finishes with the measurements on a laboratory prototype.

Research Objectives:
- Understanding the SiC Mosfet characteristics & Mosfet parallelization theory
- Deduce objective functions for Mosfet parallelization and find optimal solutions for different frequencies
- Build test setup to verify the previous results.

Collaboration with Industry: No

Contact details:
- PhD student: P. Purgat (p.purgat@tudelft.nl)
- Supervisor: F. Pansier (f.pansier@tudelft.nl), P. Bauer (p.bauer@tudelft.nl)
DEVELOPMENT OF OPTIMIZED SYSTEM AND INVERTER FOR ON-AND OFF-GRID OF A NEW HYDRAULIC WINDMILL FOCUSED ON STAND-ALONE WATER AND ELECTRICITY PRODUCTION

Type of project: MSc thesis

Scope: The scope of the project is the development of an inverter for both on-grid and off grid operation for a new type hydraulic windmill. This hydraulic windmill has been developed to offer a distributed production facility to produce water and electricity, most of the time in rural areas.

Problem definition: Especially the fact that the generator(s) are placed on foundation level allows to design a flexible system to find the most optimal layout for either generator(s) in cascade using each generator on its optimal efficiency load percentage or to balance the system between water production and electricity production in such a way that both systems are optimized. The inverters for the generator(s) are an essential element of this system.

Methodology: Taking the energy curve of a windmill versus wind speed in consideration in making a model for two cases (driving a reverse osmosis and generator, or generators in cascade) and find the optimized layout of both systems at given average wind speeds. Next should an inverter be developed to enable these settings in a flexible way, which means that at different average wind speed levels the optimum solution can be placed in operation. As this are distributed production systems both on-grid and off-grid operation should be possible.

Research Objectives:

- optimum lay-out of cascade switching of generators
- optimum lay-out for different windspeeds for the combination of reverse osmosis and generator(s) and the corresponding inverter design for that.
- A system should be built and tested in a (sub)tropical area where probably the micro grid can be enlarged with solar systems.

Contact details:

- Company contact: SolteQ Energy bv, ir. H. Rost van Tonningen
- University supervisor: P. Bauer(p.bauer@tudelft.nl)
FAULT TOLERANT PERFORMANCE OF MULTIPHASE PM MACHINE

Type of project: MSc thesis

Scope: The HiSPEM lab machine has been designed to be a fault tolerant six phase machine. The scope of this project is to test the performance of the machine under different fault modes.

Background: The HiSPEM machine has been designed for fault tolerance, high power density, very high efficiency, and increased reliability, making it a very promising candidate for aircraft applications. Previous work has successfully implemented sensor-less field oriented control (FOC) in modular design multiphase PMSM machine using distributed controllers. This is to be extended to include a study of the performance of the machine under various fault conditions.

Research Objectives:

- Develop methods to apply different faults in the machine and the controller.
- Develop fault tolerant control algorithms.
- Study performance under faults.

Collaboration with Industry: No

Contact details:

- PhD student: Udai Shipurkar (U.Shipurkar@tudelft.nl)
- Supervisor: Jianning Dong (J.Dong-4@tudelft.nl)
STRUCTURAL ANALYSIS OF LARGE, SEGMENTED PM GENERATORS

Type of project: MSc thesis

Scope: The project explores the structural requirements for the segmented design of a large (10MW) direct drive PM generator.

Problem definition: For large wind turbines the inactive structural elements become an important consideration, therefore, the support structure is an important factor for generator design. This becomes especially challenging for segmented machines as the increase in the number of separate parts adds to the complexity of the structural design. Increasing the number of segments increases the ease of maintenance, but it complicates the design of the structure. Therefore, an optimal solution for segmentation depends on the weight (and cost) of the structure.

Methodology: The project will require FEM and/or analytical models.

Research Objectives:

- Design of an effective support structure for a segmented direct drive generator.
- Analysis of the effect of number of segments on the weight and cost of the supports.
- Effect of short circuits on deflection in the structure. Is fault tolerant design required?

Collaboration with Industry: No

Contact details:

- PhD student: Udai Shipurkar (U.Shipurkar@tudelft.nl)
- Supervisor: Jianning Dong (J.Dong-4@tudelft.nl)
EFFICIENT EDDY CURRENT LOSS CALCULATION IN A FLOODED PM GENERATOR USING FINITE ELEMENT ANALYSIS

Type of project: MSc thesis

Scope: In a flooded generator, the gap between the stator and the rotor is flooded with the sea water. To protect the stator windings and the rotor magnets against the corrosive sea water, both the stator and the rotor are canned by a suitable material. This material is often electrically conductive, and eddy current losses occur within it. Such losses can become substantial with fractional slot concentrated windings. Finite element models, though more accurate compared to analytical models, are time consuming. The objective of this thesis is to speed-up the loss calculations using finite elements, for a small trade-off with accuracy, to make them suitable for optimization studies.

Problem definition: To develop time-efficient finite element models for calculating eddy current losses in a flooded PM generator with fractional slot concentrated windings.

Methodology: Finite element models, other than full transient models, shall be developed which compromise slightly on accuracy, and significantly improve time cost of the models. For instance, the Rotor-only model shown in Figure 2 gives similar results as a full transient model shown in Figure 1, with significant savings in time. This is done by modifying the original boundary conditions, resulting in a simpler problem. In this thesis, stator only models also will be required.

Research Objectives:
- To explore time-efficient FE models to calculate eddy losses, other than full transient models.
- To verify if these efficient FE models can be extended to calculating both the stator and the rotor eddy current losses in a flooded generator.
- To identify the limitations of these efficient FE methods.

Collaboration with Industry: Yes

Contact details:
- PhD student: Faisal Wani, F.M.Wani@tudelft.nl
- Supervisor(s): Dr. J. Dong, J.Dong-4@tudelft.nl
Type of project: MSc thesis

Scope: An interesting concept to increase the reliability and reduce the cost of energy from a tidal turbine is to use the flooded generator. A flooded generator is an open-to-sea generator where the stator frame is in direct contact with the sea, and the stator-rotor gap is flooded with the sea water. To protect the stator windings and the rotor magnets against the corrosive sea water, both the stator and the rotor are canned by a suitable material. In addition to the surface PM topology, which is being presently explored, another possibility is to use an interior permanent magnet rotor design, as shown in Figure 2.

Problem definition: The objective of this thesis is to develop an electromagnetic-thermal (analytical and/or finite element) model for the design of a flooded generator with an interior magnet rotor. The models developed should be suitable for optimization purposes.

Methodology: This thesis will mostly involve analytical electromagnetic design of the machine coupled with a lumped parameter thermal model. Validation for the analytical model may be done using finite element models.

Research Objectives:
- Develop EM-thermal model for a flooded generator with interior PM (IPM) rotor.
- Comparison of IPM rotor with surface PM rotor for a flooded generator.
- To determine if a solid iron rotor covered by a suitable can material or an anti-corrosion coating can be used in a flooded generator? Or, is laminated iron still necessary?
- To check the suitability of ferrite magnets for flooded generator applications?

Collaboration with Industry: Yes

Contact details:
- PhD student: Faisal Wani, F.M.Wani@tudelft.nl
- Supervisor(s): Dr. J. Dong, J.Dong-4@tudelft.nl

2 http://engineering-solutions.ru/motorcontrol/pmsm/
THE DEVELOPMENT OF A ‘CURBED WIND POWER MECHANISM’

Type of project: Master thesis

Scope: Together with Senfal you will be developing a calculation and control strategy for determining the amount of power curbed and adjusting pitch/inverter settings to deliver required reactions.

Problem definition: The frequency of alternating current as measured on power grids needs to be contained to values around 50 hz. Imbalances between energy supply and demand immediately influence frequency. Oversupply increases frequency and vice versa. Currently mismatches between supply and demand are compensated by ramping up generators of fossil fueled power plants. However, during moments when fossil power plants are pushed out of the market due to the availability of cheap wind and solar energy, these power plants will no longer be able to supply this service cost effectively. Therefore Senfal is developing the control software to deliver frequency containment reserve from a combination of wind turbines and batteries. The output of wind turbines can be controlled by adjusting the pitch of the turbine’s blades and/or inverter settings. However, with turbines, you can’t control the fuel’s input (i.e. the wind). Thus, Senfal needs to continuously (on a 10 second basis) predict the amount of power curtailed, and use this information in our control loop. Together with Senfal you will be developing a calculation and control mechanism for determining the amount of power curbed and adjusting pitch/inverter settings.

Methodology: Data analysis, control algorithm development, possible testing of developed algorithms in on selected turbines*.

Research Objectives:
- Develop a method for determining curbed power on a 10 second basis;
- Test accuracy of developed strategy;
- Define a control strategy for the combination of wind turbines and battery assets;
- Refine defined control strategy in test setting.

*Cannot be guaranteed as of yet.

Contact details:
- Company contact: Zita Divendal, work@senfal.com
- TUD supervisor: P. Bauer(p.bauer@tudelft.nl)
OPTIMAL CHARGING OF ELECTRIC VEHICLES FROM SOLAR ENERGY BASED ON PRICES AND DISTRIBUTION NETWORK CONSTRAINTS (MSC THESIS)

Type of project: Master thesis

Scope:
- Increase the penetration of EV and PV in the grid by charging of EV using PV arrays
- Energy management system design for solar powered charging of large number of EVs
- Optimisation of power flows based on grid conditions, solar forecast, and electricity prices.

Problem definition: The EV-PV project aims at developing an electric vehicle charging infrastructure at workplace using PV panels. The system provides for sustainable charging of EV from solar energy. At the same time, large-scale integration of PV and EV has adverse effects on the distribution network - Under-voltage and over-voltage at feeder end, overloading of lines and distribution transformers. In this MSc thesis, an energy management system will be designed that performs the optimisation of power flows in a solar powered EV charging station considering the distribution network constraints.

Methodology:
1. Understand the optimisation and power flow simulation models built in two past MSc thesis in the group. The first thesis focusses on optimal EV charging based on PV and prices. The second thesis focuses on optimal EV charging based on distribution network constraints.
2. Create an interface between the two systems in GAMS and Matlab.
3. Simulation of scenarios in MATLAB/GAMS based on solar/grid/price to maximise EV charging from PV and supply loads with minimum grid dependency/cost.
4. Apply the model to a typical Dutch distribution network to analyse the benefits.

Preferred background: Power systems, optimisation, MATLAB, GAMS, Power factory

Collaboration with Industry: No

Contact details:
- PhD student: Gautham Ram, Seyedmahdi G.R.ChandraMouli@tudelft.nl
- Supervisor: Pavol Bauer P.Rauer@tudelft.nl
COMMON MODE VOLTAGE SUSPENSION IN MODULAR MULTI-PHASE PERMANENT MAGNET MACHINE

Type of project: MSc Thesis

Scope: The scope of this project is to find suitable control scheme to suspend the common mode voltages for the modular designed multi-phase permanent magnet machine.

Problem Definition: Multiphase machine with modular design which integrates the power converters with phase modules is an appealing solution for high reliable applications such as aircraft. The modular design isolates each phase, thus can reduce the failure rate. However, as there is no common neutral point for the multi-phase system, it is prone to generate common mode voltage, which reduces the system efficiency and bearing life. Suitable control scheme and modulation technique are needed to suspend the common mode voltage.

Methodology: Numerical simulation, laboratory work and programming are involved in this project.

Research Objectives:

- To find possible causes of common mode voltage.
- To propose methods to reduce the common mode voltage.
- To validate the proposed methods via simulations and experiments.

Collaboration with Industry: No

Contact details:

- Supervisor: Jianning Dong (J.Dong-4@tudelft.nl, LB03.630)
EXPERIMENT SETUP UPGRADE FOR THE ELECTRICAL MACHINE COURSE

Type of project: Extra Project

Scope: Upgrade the existing experiment setup in the Telegen Hall for better synchronous machine experiment.

Problem definition: The experiment setup for the course electrical machines and drives in the Telegen Hall is composed by an induction machine, a synchronous machine and a DC machine. The three machines are coupled to the same shaft. The rated torque of the DC machine is lower than the other two. Currently DC drive in torque control mode is used as the drive/load in the synchronous machine experiment. However, the torque of the DC machine is not high enough, which makes the experiments rather difficult to do. We want to upgrade the setup by using the induction machine in torque control mode as the drive/load when doing the synchronous machine experiment.

Methodology: Implement the torque control loop of the induction machine through Siemens Sinamics platform.

Research Objectives: Torque control of induction machine

Collaboration with Industry: No.

Contact details:
- Supervisor: Jianning Dong, J.Dong-4@tudelft.nl.
- Harrie Olsthoorn, H.J.M.Olsthoorn@tudelft.nl.


NOISE ANALYSIS FOR LARGE TORQUE LOW SPEED MODULAR PERMANENT MAGNET MACHINE

Type of project: MSc Thesis

Scope: The scope of this project is analysis of acoustic noise and vibration for the large torque low speed permanent magnet (PM) machine with modular stator structure.

Problem Definition: Large torque low speed PM machines are extensively used in direct-drive applications, e.g. wind turbines, electric vehicle wheel-hub drive and elevators. Fractional slot winding and modular stator are frequently used for these machines to reduce the cost and improve the efficiency, which also increases the risks of high vibrational and noisy operation. Therefore, the influence of modular stator structure on the dynamic behaviour of the stator should be investigated. An analysis procedure which can predict the noise resulted from the radial electromagnetic force acting on the stator inner surface has to be completed. Suggestions on structure, manufacturing process and control have to be made based on the analysis results to reduce the noise.

Methodology: Analytical modelling, numerical simulation and programming are involved in this project.

Research Objectives:

- To understand the influence of modular structure on electric machine vibration and noise.
- To create models for noise prediction of large torque low speed PM machines.
- To make proposals for noise reduction of large torque low speed PM machines.

Collaboration with Industry: No

Contact details:

- Supervisor: Jianning Dong (J.Dong-4@tudelft.nl, LB03.630)
NOISE PREDICTION AND MEASUREMENT OF BRUSHLESS DOUBLY-FED INDUCTION MACHINE

Type of project: MSc Thesis

Scope: The scope of this project is to calculate noise of the brushless DFIM then verify the theoretical analysis through measurement.

Problem Definition: The brushless doubly-fed induction machine have two main magnetic field components in the air gap, which makes its vibration and noise behaviour different from conventional machines. A fast noise prediction model should be built to calculate its noise from its air-gap flux density harmonics. A measurement system which can measure the noise, current waveforms and surface vibrations simultaneously has to be designed and built. The measured results should be analysed to validate the prediction by using waterfall diagram.

Methodology: This project includes numerical simulation, laboratory work and programming.

Research Objectives:

- To build a dynamic circuit model of the brushless DFIM considering harmonics.
- To develop a fast noise prediction method for the brushless DFIM.
- To build an electric machine noise measurement system.

Collaboration with Industry: No

Contact details:

- Supervisor: Jianning Dong (J.Dong-4@tudelft.nl, LB03.630)
SMALL WIND TURBINES IN SMART CITIES: OPPORTUNITY ASSESSMENT

Type of project: MSc Thesis

Small wind turbines installed in Shanghai Tower, source: http://du.gensler.com

Scope: Opportunity assessment of small wind turbines in aspects of wind turbine structures, generator types, suitable locations, life time cost and energy yield, with context of smart cities.

Problem definition: Megawatts wind turbines have been successful globally. However, there is still no unique conclusion for small wind turbines with household or commercial power ratings (100 W to 100 kW), especially with context of smart cities. What power rating is optimum? What power-train and generator type is most suitable? Where are the suitable locations and scenarios? What can we do to make them more appealing? Whether they are economically feasible? Do they fit the vision of smart cities? This thesis will answer these questions by doing research into various aspects with regards to the opportunity of small wind turbines.

Methodology: The project includes literature review, modelling and simulation.

Research Objectives:

- Overview of the state of art of small wind turbine technologies.
- Modelling the small wind turbines with consideration of economic aspect.
- Case studies of small wind turbines in smart cities.

Collaboration with Industry: No.

Contact details:

- Supervisor: Jianning Dong, J.Dong-4@tudelft.nl
  Pavol Bauer, P.Bauer@tudelft.nl
Type of project: MSc thesis

Scope: This master project will focus on system identification of the motor thermal model. An accurate model of the motor's thermal behaviour can be used to increase the permissible torque of the motor, or to detect system degradation. Improvements in accuracy can possibly be obtained by using additional sensors, such as phase current.

Problem definition: Additionally to the integrated temperature sensors of the electric machine an estimation of the temperatures is required to optimize the performance availability of the electric machine. This due to delays in the system caused by thermal resistances towards the measurements. Accurate estimation relies on the loss model, physical structure of the cooling system and phase current balance.

Methodology: During this master project you will develop a thorough understanding of a three phase inverter and PMSM motor, develop the motor thermal loss model, design system identification tests, perform measurements in our laboratory and design an estimator that can be implemented in real time.

Research Objectives:

- Development of a thermal loss model of the electric machine.
- Thermal loss model validation using measurement data.
- Development of an accurate real-time executable temperature estimator.

Collaboration with Industry: Yes, e-Traction

Contact details:

- Company contact: Patrick Hendriks  
  p.hendriks@e-traction.com
- TUD supervisor: Pavol Bauer, P.Bauer@tudelft.nl
COMPARATIVE STUDY OF SWITCHED RELUCTANCE MOTORS APPLIED FOR VARIOUS APPLICATIONS OF ELECTRIC VEHICLES

Type of project: MSc thesis / Extra Project

Scope: Switched reluctance motors (SRMs) have attracted increasing attention from the automotive industry due to their robust structure and relatively low price. This project is aimed at obtaining an overview of the capabilities of SRMs for application in various types of electric vehicles.

Problem definition: The torque-speed requirements for the motor used in electric vehicles are highly dependent on the type of vehicles, e.g. small- or large-size, and traction topologies, e.g. in-wheel, wheel-hub, or axle drive. Hence, the optimal choice of motor topology and dimensions is case sensitive, while the limitations and boundaries for implementing SRMs into various vehicle applications need to be researched.

Methodology: This work is to be proceeded in two approaches:

- Survey based on literature study
- Simulation using finite element analysis and MatLab/Simulink

Research Objectives:

- Literature review on state of the art of SRMs applied for electric traction
- Quantitative comparison on sizes and torque-speed characteristics of SRMs designed for different applications.
- Model-supported recommendations for design and implementation

Collaboration with Industry: Yes, e-Traction

Contact details:

- Company contact: Yang Tang, y.tang@e-traction.com
- TUD supervisor: Pavol Bauer, P.Bauer@tudelft.nl
ENERGY OPTIMIZATION OF THE DIRECT-DRIVE IN-WHEEL MOTOR POWERTRAIN

Type of project: MSc thesis

Scope: The focus of the assignment is to develop an energy optimization strategy that employs the degrees of freedom available in TheMotion system. An important aspect of this assignment is the preservation of driving comfort and vehicle dynamic behaviour.

Problem definition: TheMotion system consists of two or more direct-drive in-wheel motors that can be operated in four quadrants. This provides several possibilities to optimize the energy consumption of a drive-cycle. However the strategy should take the following vehicle aspects into account: performance, driving comfort and dynamic behaviour.

Methodology: This strategy will be developed and modelled using Matlab Simulink and will be verified by vehicle behaviour simulation and actual vehicle testing.

Research Objectives:

- Extending the e-Traction vehicle model such that it is suitable for accurate drive-cycle energy consumption analysis.
- The development of a powertrain control strategy optimized for energy efficiency.
- The objective validation of the strategy using model validation and vehicle testing.

Collaboration with Industry: Yes, e-Traction

Contact details:

- Company contact: Geert Kwintenberg
g.kwintenberg@e-traction.com
- TUD supervisor: Pavol Bauer, P.Bauer@tudelft.nl
MEDIUM-SPEED MEDIUM-TORQUE PERMANENT MAGNET SYNCHRONOUS MOTOR FOR AXLE-DRIVE ELECTRIC BUS

Type of project: MSc thesis / Extra Project

Scope: Due to different torque-speed requirements, electric motors designed for in-wheel and axle-drive applications are often distinct. This division limits the market and increases the production costs of the motor. This project is aimed at incorporating an existing design of an in-wheel permanent magnet synchronous motor (PMSM) into a different axle-drive application, in which the feasibility and limitations are to be investigated.

Problem definition: The feasibility of implementing an existing design of an in-wheel PMSM into a specified axle-drive electric bus needs to be investigated. Limitations and necessary design modifications need to be proposed and validated using simulation.

Methodology: This work shall be proceeded in two approaches:

- Survey based on literature study
- Simulation using finite element analysis and/or MatLab/Simulink

Research Objectives:

- Quantitative comparison on the size and mass of the PMSMs required for applications with various torque-speed requirements.
- Feasibility analysis and redesign of the existing in-wheel motor for an axle-drive application.
- Limitations, and recommendation on the redesign.

Collaboration with Industry: Yes, e-Traction

Contact details:

- Company contact: Yang Tang, y.tang@e-traction.com
- TUD supervisor: Pavol Bauer, P.Bauer@tudelft.nl
DC SIMULATION MODEL LIBRARY

DEVELOPMENT OF FAST SIMULATION MODELS FOR DC GRIDS.

Type of project: Extra Project / Sip-2 Project

Scope: DC grids are emerging. Research and development for DC grids are ongoing and heavily relies on modeling and simulation. There are various models in existence that can be used to model DC grids and its connection to the AC grid. However these models are user specific and no universal standard exist.

Problem definition: Develop a simulation model library for DC components, such that it ensures fast and stable simulation runs, while preserving easy to understand parametrisation of the models.

Methodology: A new model library for components used in DC grids has to be developed with the following specifications:

- Universal interface for the models, so users can build complete systems from single models.
- Applications include High-voltage, Low-voltage grids, as well as existing and emerging power electronics topologies, power cables and loads.
- The model should be able to perform transient simulations as well as steady state.
- Parameters and underlying equations for each model have to be documented in detail, so the user understands the possibilities, but also the limitations of the model.
- Web interface where users can download the library and documentation.

Research Objectives: This work aims at developing the library using Matlab/Simulink

- Perform a literature survey of existing models and methods.
- Collect, adapt to the universal interface and document existing models already developed.
- Development of new models based on mathematical relations and/or experimental data.
- Documenting each model into detail and creating a web based user manual.

Collaboration with Industry: No

Contact details:

- Daily supervisor: Dr. Ir. Peter van Duijsen, P.J.vanDuijsen@tudelft.nl;
- Supervisor: Dr. Ir. Pavol Bauer, p.bauer@tudelft.nl
MASTER’S THESIS PROPOSAL

BLOCKCHAIN FOR DC DISTRIBUTION GRIDS

**Type of project:** MSc thesis

**Scope:** In the future, it is expected that the blockchain will play a big role in the trading of distributed sustainable energy. The goal is to identify the advantages and challenges of applying blockchain technologies to the (dc) distribution grid.

**Problem definition:** Smart grids are designed to support the integration of local production and consumption of a large number of “prosumers” (both producer and consumer). The goal is to transport the surplus of energy from one participant to another in the smart grid. However, with increasing physical distance, the electrical energy travels more energy is dissipated. Therefore, the management of the smart grid should prioritize the local use of the energy. It is not logical to manage smart grids in a traditional (centralized) fashion as this would likely be very costly. Consequently, a decentralized method is most likely preferred. It is hypothesized that the blockchain technology is an effective solution for the task of automating the management of smart grids.

**Methodology:** This work will mainly involve a literature study, critical thinking, and possibly programming.

**Research Objectives:**

- Perform a literature study on the applications of blockchain
- Evaluate various blockchain technologies
- Identify the advantages and challenges of blockchain technologies for (dc) distribution grids
- Analyse case studies

**Collaboration with Industry:** No

**Contact details:**

- PhD student: Nils van der Blij; N.H.vanderBlij@tudelft.nl, Pavel Purgat; P.Purgat@tudelft.nl
- Supervisors: Prof. Dr. Eng. Pavol Bauer; P.Bauer@tudelft.nl, Dr. Ir. Laura Ramirez-Elizondo; L.M.RamirezElizondo@tudelft.nl
DEMAND SIDE MANAGEMENT IN DC GRIDS

Type of project: MSc thesis

Scope: Demand side management (such as demand response) can be used to improve the utilization of renewable (distributed) resources, efficiency and stability of distribution grids. The goal is to create demand side management algorithms for dc distribution grids.

Problem definition: With the introduction of renewable (distributed) energy resources the peak of supply and demand cannot be matched perfectly. Shifting the supply peak by utilizing storage is a very costly solution. Therefore, demand side management is preferable. Several strategies exist to shift the demand. Demand side management refers to initiatives and technologies that encourage consumers to optimize their energy use.

Methodology: This research project will mainly involve a literature study, creative thinking and simulations.

Research Objectives:

- Literature study on demand side management techniques
- Development of (novel) demand side management algorithms
- Application of demand side management algorithms in simulation environment
- Analyse case studies

Collaboration with Industry: No

Contact details:

- PhD student: Nils van der Blij; N.H.vanderBlij@tudelft.nl
- Supervisors: Prof. Dr. Eng. Pavol Bauer; P.Bauer@tudelft.nl, Dr. Ir. Laura Ramirez-Elizondo; L.M.RamirezElizondo@tudelft.nl
MODELLING OF DC DISTRIBUTION GRIDS

Type of project: MSc thesis

Scope: To support research on, for example, the control and protection of DC distribution grids new analysis tools are required. The goal is to create tools to analyse DC Distribution grids in steady state, dynamic, and/or transients conditions.

Problem definition: The advances in power electronics have made it equally simple to transform DC as AC voltages nowadays. In the (near) future, DC is estimated to have advantages over AC in terms of transmission, efficiency, converters, and control. However, the broad adoption of DC distribution systems still faces several challenges. Many of these challenges can be found in the control and protection of DC distribution systems. Previous research into DC distribution systems present several methods to analyse DC distribution systems. However, these approaches generally lack in accuracy, flexibility, computational speed, and/or ease of use. Moreover, these models are often designed for a specific simulation environment. Therefore, the creation of new accurate, flexible easy to use models is required.

Methodology: This work will mainly involve a literature study, mathematical derivations and simulations.

Research Objectives:

- Identify modelling methods of (DC) distribution grids
- Develop a (novel) DC distribution grid model
- Verify the distribution grid model empirically or via existing models
- Analyse case studies

Collaboration with Industry: No

Contact details:
- PhD student: Nils van der Blij; N.H.vanderBlij@tudelft.nl
- Supervisors: Prof. Dr. Eng. Pavol Bauer; P.Bauer@tudelft.nl, Dr. Ir. Laura Ramirez-Elizondo; L.M.RamirezElizondo@tudelft.nl
STABILITY OF DC DISTRIBUTION GRIDS

Type of project: MSc thesis

Scope: The stability of future (dc) distribution grids is challenging. The goal is to analyse the stability of dc distribution grids by using impedance criteria, small signal analysis, and/or eigenvalue analysis.

Problem definition: Stability of dc distribution grids, and the stability of future ac distribution grids, is a relatively new topic. Compared to current distribution grids these grids have little inertia, contain lots of constant power loads, and have complex (meshed) architectures with many sources and loads. Therefore instability is expected to occur more easily. Another important issue is the sizing of the components such as converter output capacitance and filter inductance. These components influence the stability, control and protection of dc distribution grids.

Methodology: This work will mainly involve a literature study, mathematical derivations and simulations.

Research Objectives:

- Identify stability analysis methods for (DC) distribution grids
- Develop a (mathematical) approach to analysing DC distribution grid stability
- Verify the distribution grid stability via given models
- Determine optimal sizing for system components
- Analyse case studies

Collaboration with Industry: Direct Current BV

Contact details:

- PhD student: Nils van der Blij; N.H.vanderBlij@tudelft.nl
- Supervisors: Prof.Dr. Eng. Pavol Bauer; P.Bauer@tudelft.nl,
  Dr. Ir. Laura Ramirez-Elizondo; L.M.RamirezElizondo@tudelft.nl
MASTER'S THESIS PROPOSAL

SMART GRIDS ON DISTRICT LEVEL

Type of project: Extra Project

Scope: The scope of this project is to search for solutions and possibility's (smart grids) to preserve energy on district level. A search for processes to energetic optimization of a district with a focus on Housing Corporation property. Solutions for district optimization can be delivered, which can be used for any district in different formations.

Problem definition: Many power generation systems, such as cogeneration, usage of biomass, usage of waste heat and usage of waste for production of energy and heat, will become more viable on a higher power level. These are therefore pre-eminently convenient for neighbourhood-based approach. The usage of the possibilities of the specific district, in combination with the optimization of the whole area system, could lead to a comparable return as low energy buildings.

One of the problems is that there are no standard solutions and that the solutions always need to be adapted on the possibilities of the specific district. The process for energetic optimization of a district will be more complicated and will remain longer. Also, a neighbourhood-based approach will be, in general, only achievable in combination with another transformation aspect, such as shifting usage or, if the district has to be tackled because of social grounds, by perhaps several corporations of the concerning district.

Besides the approach of the production of energy and heat, and the reduction of the demand, an optimization of the distribution will become more important. Decentralized supply of energy, storage and distribution require more flexibility of the network. Smart grids will connect the users, the decentral and the central suppliers and storage with each other.

Methodology: First a literature study has to be made. Typical applications, upcoming developments in the district, requirements and demand response potential in nationwide communities have to be estimated. (delivery and upcoming plans from energy suppliers or corporations). After this, matching solutions (smart grids) will be developed, which have to suit the developments in the district and have to be technically feasible. The people and knowledge of our organization can be involved in this very well.

Research Objectives:

- Establish developments on district level
- Establish developments on political/corporation level
- Research new developments in the market

Collaboration with Industry: Hemubo

Contact details:

- Company contact: Niels van Surksum; N.vanSurksum@Hemubo.nl
- TUD supervisor: Prof. Dr. Eng. Pavol Bauer; P.Bauer@tudelft.nl
INTEGRATION OF ELECTROCHEMICAL CO2 UTILIZATION PROCESS WITH THE RENEWABLE ENERGY GRID

Type of project: MSc thesis

Problem definition: Anthropogenic CO2 emissions are a major contributor to global warming and are expected to have wide-spread and irreversible impact on human and natural systems. Electrochemical reduction of CO2 using renewable electricity is a very attractive means to (1) reduce atmospheric accumulation of CO2 (2) store excess renewable electricity in a chemically useful form (3) to produce valuable fuels and chemicals in a sustainable way.

Research Objectives:

- Propose solutions to integrate the CO2 electrochemical reduction process to the renewable electricity grid.
- Optimize the integration as a function of scalability and costs within constraints of the electrochemical system.
- Derive practical challenges this integration poses for the electrochemical system to guide future research and development.

Collaboration with Industry: No.

Contact details:
- PhD candidate: Divya Bohra (TNW faculty), D.Bohra@tudelft.nl
- Supervisor: Pavol Bauer, p.bauer@tudelft.nl
Type of project: MSc thesis

Scope: In order to decrease the initial costs and the complexity of PV-battery normal installations, we propose a PV-Battery Integrated Module (PBIM). This novel concept could result in an interesting solution for the solar energy market. The PBIM includes a suitable battery, dc/dc converter with maximum power point tracker, dc/ac microinverter, and a battery management system.

Problem definition: This project focuses on the implementation of an energy management system (EMS) for the PBIM. The EMS controls the power flows of the device according specific modes of operation. The EMS must include a battery balancing system (BMS), that calculates the SoC and SoH of the battery pack, taking into account the temperature, voltage, and c-rate.

Methodology: This project is divided into three main parts. The first part is the implementation of EMS using a Texas Instruments C2000 for a low power PV panel, while in the second part a design of EMS for a PV panel of higher power is proposed. The third part is related to the implementation of BMS using the Texas Instruments EM 1401 board.

Research Objectives:
- Implement an EMS using the Texas Instruments board C2000
- Propose an EMS for a PV panel with higher power output (~around 250W)
- Implementation of BMS using the Texas Instruments EM 1401 board.

Collaboration with Industry: No

Contact details:
- PhD student: Victor Vega Garita, v.e.vegagarita@tudelft.nl
- Supervisors: Laura Ramirez (L.M.RamirezElizondo@tudelft.nl)
  Prof. Paul Bauer (P.Bauer@tudelft.nl)
TESTING OF PV-BATTERY INTEGRATED MODULE PROTOTYPE

Type of project: MSc thesis

Scope: In order to decrease the initial costs and the complexity of PV-battery normal installations, we propose a PV-Battery Integrated Module (PBIM). This novel concept could result in an interesting solution for the solar energy market. The PBIM includes a suitable battery, dc/dc converter with maximum power point tracker, dc/ac microinverter, and a battery management system.

Problem definition: Due to the fact that a single PV-Battery Integrated Module is a novel concept, the aim of this project is to evaluate its efficiency and thermal response. Hence, the voltages and currents produce or consumed by the PV panel, batteries, and load must be measured to estimate the efficiency of the prototype and the functioning of the device. Moreover, because the operation temperature of the batteries is the most critical aspect when integrating PV and batteries in the same device, the temperature of the batteries and other components have to be measured while testing.

Methodology: This project is heavily based on experimental work. In particular, indoors and outdoors testing must be carried out.

Research Objectives:

- Characterize the electrical and thermal response of the PBIM under a solar simulator.
- Improve the design of the prototype for outdoor testing.
- Characterize the electrical and thermal response of the PBIM in outdoors testing.

Collaboration with Industry: No

Contact details:

- PhD student: Victor Vega Garita, v.e.vegagarita@tudelft.nl
- Supervisors: Laura Ramirez (L.M.RamirezElizondo@tudelft.nl) Prof. Paul Bauer (P.Bauer@tudelft.nl)
**Master’s Thesis Proposal**

**Type of project:** Msc. Thesis

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**Scope:** Defining a typology of battery systems and develop algorithms to define the ability of each to contribute to providing frequency containment reserve.

**Problem definition:** In the future our software (SenfalCore) will connect to various types of batteries. Various batteries have different capabilities: some can effectively discharge large amounts of power, others cannot; some are accurate in their control, others less so. Senfal needs to develop a mechanism that classes different types of batteries and is able to divide tasks between systems for providing stable and accurate frequency containment reserve (FCR). Due differences in the accuracy and sizes of delivered power, battery systems contribute differently to the provision of FCR. They should therefore be remunerated differently. Those who contribute most, should be allocated the most return. Such an allocation mechanism will be part of this thesis.

**Methodology:** Typology based on market research and literature study. Preferably create dummy batteries based on assumptions and model pool behavior. From that define an allocation method. If necessary two types of batteries can be selected for testing purposes.

**Research Objectives:**
- Define battery typology and reaction characteristics
- Model pool behavior of realistic set of distributed batteries for the provision of FCR
- Define allocation method for compensating battery owner for their contribution to providing FCR

**Contact details:**
- Company contact: Zita Divendal, work@senfal.com
- TUD supervisor: Pavol Bauer, P.Bauer@tudelft.nl
FREQUENCY CONTAINMENT RESERVE FROM ELECTRIC VEHICLES

Type of project: Master Thesis

Scope: Our software package (SenfalCore) will connect to thousands of charging stations. The challenge is to predict the available amount of flexibility accurately.

Problem definition: Our software package (SenfalCore) will connect to thousands of charging stations. Getting a rough prediction of the available amount of flexibility (power that can be shifted throughout time) is relatively easily solved; we can connect data of the driver and their charging pattern. Next to this; how are the chargepoint owner and Senfal going to communicate the value of shifting demand? These are questions you would be working on during your thesis.

Methodology: Heavy focus on data analysis (large amounts of data). Predictive modeling.

Research Objectives:
- Data analysis; grouping of charging behavior profiles
- Modeling and predicting amount of available controllable load
- Define a bidding mechanism to trade available shiftable load.

Contact details:
- Company contact: Zita Divendal, work@senfal.com
- TUD supervisor: Pavol Bauer, P.Bauer@tudelft.nl
STACKING DR SERVICES

Type of project: Master Thesis

Scope: For our pools of coldstores, batteries, turbines etc. we need to develop the technology to combine FCR and demand response (APX / secondary reserve) reactions. You will develop a mechanism that will optimize control decisions on the pool level.

Problem definition: In order to build a profitable business case around sustainable energy generation assets, we need to determine control decisions of our software based on market signals. Various market signals can be distinguished; for example, we take into account day-ahead (APX), imbalance (TenneT secondary reserve) and frequency containment reserve (FCR) markets. Ultimately optimization between these market will be done at the aggregated level (pools of coldstores, batteries, turbines etc.). For our pool we now need to develop the technology to combine FCR and demand response (APX / secondary reserve) reactions. You will develop a mechanism that will optimize control decisions on the pool level.

Methodology: Mostly data analysis and algorithmic work, based on desk research. You will build upon existing work done by Senfal.

Research Objectives:
- Define groups within the pool of assets under Senfal’s control
- Define the amount of flexibility services that can be delivered by the pool
- Define control algorithm for delivering most optimal dispatch of flexible load within pool

Contact details:
- Company contact: Zita Divendal, work@senfal.com
- TUD supervisor: Pavol Bauer, P.Bauer@tudelft.nl
ADVANCED ACTIVE & REACTIVE POWER CONTROL STRATEGIES FOR DISTRIBUTED MULTI-SERVICE BATTERY ENERGY STORAGE SYSTEMS

Type of project: MSc thesis

Research Objective: To formulate and develop advanced active and reactive power control strategies for distributed multi-service battery energy storage systems.

Scope & Problem definition: Due to the dramatic increase in the penetration rate of renewable energy sources like solar and wind, electrical networks are currently facing various technical challenges (e.g., large voltage variations). To overcome these problems, battery energy storage systems (e.g., Tesla PowerPack and Tesla Powerwall) are an effective and viable solution, however they are still relatively expensive. In order to make battery systems more cost-effective in the near future, they are to simultaneously provide a wide variety of electricity ancillary services (e.g., voltage control and energy arbitrage) within electrical networks. To achieve this end, the active and reactive power of multi-service battery energy storage systems are to be optimally controlled. The problem becomes even a more complex and challenging task, as the trade-off between the battery life and the performance of multi-service battery energy storage systems shall be also taken into account. Therefore, advanced control strategies for battery energy storage systems are required to be proposed and developed to optimally provide a number of electricity services, while preserving the battery life.

Methodology:

1. Identify electricity ancillary services, which could be potentially provided my multi-service battery energy storage systems
2. Develop advanced active and reactive control strategies for multi-service battery energy storage systems taking into account the battery life
3. Study and simulate the proposed active and reactive power control strategy in a sophisticated software
4. Compare the performance of the proposed strategy to the previously developed strategies

Contact details:
- Seyedmahdi Izadkhast, S.Izadkhast@tudelft.nl, Gautham Ram, G.R.ChandraMouli@tudelft.nl
- Supervisor: Pavol Bauer, p.bauer@tudelft.nl
MULTIPLE GROUNDING POINTS IN DC DISTRIBUTION GRIDS

Type of project: MSc thesis

Scope: Grounding is an important topic in DC Distribution Grids. DC ground currents can cause corrosion. In this thesis it is to be further investigated how multiple grounding points are should be realized in dc. Lightning as the most severe fault should be considered.

Problem definition: “Using the AC grounding methods, such as resistive grounding, proves problematic. As a matter of facts, as there are several grounding points in the network, they form a loop in the ground where the current can flow. If the voltage across the grounding points is not null, then a current will be able to flow through the ground. In AC, this was not such a problem, but DC ground currents will corrode the infrastructure around the network, which will prove harmful over time. It is thus necessary to devise a new way of grounding the system. “1

Methodology: In the first phase student will familiarize with grounding practices through the literature study and cooperation with the industrial partner.

Research Objectives:

- Identify the ground types and magnitudes that can be expected in DC distribution grids
- Create simulation model for the analysis of these ground faults
- Investigate possible grounding measures and protection schemes

Collaboration with Industry: Yes, Direct Current B.V.

Contact details:

- PhD student: P.Purgat (p.purgat@tudelft.nl)
- Laurens Mackay (l.j.mackay@tudelft.nl)
- Supervisor:
  - Laura Ramirez Elizondo
  - Pavol Bauer, p.bauer@tudelft.nl

1 MSc Thesis Elisabeth Vandeventer, “Residual Current Protection of a Meshed DC Distribution Grid with Multiple Grounding Points”, 2016
**SOLID-STATE HYBRID CIRCUIT BREAKER OPTIMIZATION**

**Type of project:** MSc thesis

**Scope:** Protection is the main challenge to be solved for dc grids to emerge from small dc nano- and microgrids to a full scale dc distribution grid. Opening circuits is not as easy as in ac systems due to the missing current zero-crossing that supports eliminating switching arcs.

**Problem definition:** Power electronics of converters have a limited over-current withstand capability (around 2-3 times the nominal load current for tens of μs. Oversizing these converters for higher currents is possible, but expensive. Option is to oversize only the output capacitors which are the first providers of short-circuit energy. In power electronics the trend is to increase the switching frequency in order to reduce the size of passive components such as capacitors and thus material usage and cost. All components and cables need to be able to withstand the thermal stress and electromagnetic forces that act in case of short circuit.

**Methodology:** In the first phase student will familiarize with the protection practices through the literature study and cooperation with the industrial partner. The core of the work load is in the optimization and defining the objective functions for optimal design of the circuit breaker for high power LVDC system.

**Research Objectives:**
- Defining objective functions for the circuit breaker optimization
- Optimizing a hybrid solid state circuit breaker for 50kW rating
- Field testing on the site of the industrial partner and realization of the laboratory prototype

**Collaboration with Industry:** Yes, Direct Current B.V.

**Contact details:**
- PhD student: P.Purgat (p.purgat@tudelft.nl), Laurens Mackay (l.j.mackay@tudelft.nl)
- Supervisor: Laura Ramirez Elizondo, Pavol Bauer, p.bauer@tudelft.nl
Type of project: MSc thesis

Scope: Recent developments in off-grid rural electrification have been largely based on the use of Solar Home Systems (SHS). While this seems to be a much needed, mitigating trend to alleviate energy poverty in base of pyramid (BoP) contexts in developing nations, independent SHS are still largely limited in the power they can deliver and the kind of household loads they can power. In order to better utilize the individual storage components and power different kinds of loads, an inter-connected, DC micro-/nanogrid approach needs to be developed.

Problem definition: Until now the control of DC microgrids has mainly focused on single bus systems with one voltage level. However for interconnecting solar home systems multiple voltage levels are more promising. The methods of controlling the interaction between these sub-systems should be investigated in this thesis and shown in laboratory setup.

Methodology: The research starts with theoretical and simulations based investigation of distributed control in DC microgrids comprising multiple voltage levels. Once a satisfying method has been found it will be implemented on an existing converter prototype. Then a couple of additional converters will be built and coordinated control implemented.

Research Objectives:

- Investigating control of interconnected solar home systems with multiple voltage levels.
- Implementing control on existing converter prototype
- Building more converters and implementing coordinated control

Collaboration with Industry: No

Contact details:

- PhD student: Laurens Mackay, L.J.Mackay@tudelft.nl; Nishant Narayan, N.S.Narayan@tudelft.nl;
- Supervisor: Laura Ramirez Elizondo, Pavol Bauer
DESIGN OF A BIDIRECTIONAL FLYBACK CONVERTER TO ENABLE POWER-SHARING BETWEEN SOLAR HOME SYSTEMS IN DEVELOPING NATIONS

Type of project: MSc thesis

Fig. 1 SHS in a rural scenario
Fig. 2 Possible architecture with the flyback converter

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.

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 design of a bidirectional flyback converter rated around 300 W. It will be used to connect an extra low voltage (48V) solar home systems to higher power loads and a DC grid connecting multiple of these systems at 350V.

Methodology: The research mainly consists of a thorough design of the converter topology, along with accurate loss modelling and component selection for an actual hardware implementation later in the thesis. Control has to be implemented after building the prototype.

Research Objectives:

- Modelling the various loss mechanisms accurately for a bidirectional flyback converter.
- Hardware design after an optimal component selection (resulting from the modelling).
- Testing the designed converter on an in-house DC-nanogrid laboratory setup.

Collaboration with Industry: No

Contact details:
- PhD students: Nishant Narayan, N.S.Narayan@tudelft.nl; Laurens Mackay, L.J.Mackay@tudelft.nl
- Supervisor: Laura Ramirez Elizondo, Frans Pansier, Pavol Bauer
DC MICROGRIDS / DC DISTRIBUTION GRIDS

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

Scope: Today most loads are use DC. Even AC motors are more and more driven by motor controllers using AC/DC followed by DC/AC conversion which allows variable speed control. Distributed renewable energy sources are either DC inherently, e.g. photovoltaics, or use a DC link to decouple rotations speeds from the ac grid such as wind power. Batteries are DC in general and their application is evolving in electric vehicles and other devices. Therefore it is look into using DC to connect all these DC sources and loads.

Our research focusses on finding the “best” low voltage DC distribution system, implementing all smart grid features needed in future. This can then be put into standards for a universal DC distribution system.

Problem definition: If you have a good idea that you would like to look into, feel free to propose that. We are quite open for new ideas. Some interesting topics could be:

- Bipolar DC grid architectures
- Meshed DC distribution grids
- Dynamic pricing, distributed market models
- Distributed solution of optimal power flow
- Demand response
- Control of DC microgrids making use of short term and longer term storage
- Protection
- Designing/building hardware or software for our lab setup could be included.

Methodology: We work with simulations but we are also building a real DC lab to verify our findings. As the usual voltages are 350V-400V we can build it 1:1. The lab grid will consist of a number of DC/DC converter. All of them will be programmed using Simulink.

Collaboration with Industry: No

Contact details:
- PhD student: Laurens Mackay, lj.mackay@tudelft.nl
  Supervisor: Laura Ramirez Elizondo, Pavol Bauer
DC EXPANSION MODEL FOR THE GOVERNANCE OF THE EUROPEAN NORTHERN SEAS OFFSHORE GRID

Type of project: MSc thesis

Scope: The Northern Seas offshore grid is a priority electricity corridor of the European Union, and an important building block to the European energy transition. It is driven by HVDC transmission innovations, significant cost reductions for offshore wind, and the integration of European power systems. Climate policy, the integration of renewable sources and of electricity markets are also driving new long-term expansion planning models for the European power system.

Problem definition: The grid expansion involves multiple levels (European and national) and multiple actors such as generators and consumers. However, there is no European governance framework for planning of the offshore grid. The Offshore Grid Exploratory Model (OGEM) creates offshore grid pathways considering governance constraints, to support governance design. OGEM is already operational and open-source, but there is potential to improve the model so others can use it and to add features to study the offshore grid governance.

Methodology: OGEM is a mixed-integer linear program (MILP) expansion planning model for offshore transmission and wind power in the Northern Seas of Europe. It is a mixed-integer modification of the open-source PyPSA power system analysis tool, leveraging Pyomo (a python optimization modelling package) and other python mathematical computing and data analysis libraries. It develops exploratory expansion plans for 2030-2050 using data from the e-Highway2050 project, representing European power systems with a detailed clustered model. During the project the M.Sc. candidate will thus learn about power systems modelling and regulation, linear and mixed-integer mathematical optimization, and programming in Python.

Research Objectives:

- Validation and verification of OGEM codes for open-source publication
- Improve the performance of OGEM and the optimization library
- Develop new OGEM data analysis and visualization methods
- Conduct governance case studies with new governance constraints in OGEM

Collaboration with Industry: Collaboration with PyPSA academic developers if desired

Contact details:

- PhD candidate: João Gorenstein Dedecca (TBM faculty), j.dedecca@tudelft.nl
- Post-doc fellow: Seyedmahdi Izadkhast, s.izadkhast@tudelft.nl
- Supervisor: Pavol Bauer, p.bauer@tudelft.nl
Type of project: MSc thesis

Scope: The existing ac link between two substations needs to be converted into a dc link system. Think of how to interconnect the system to have maximum infrastructural utilization and showcase the operational modes of the new system.

Problem definition: Designing an ac to dc link refurbishment scheme with maximum existing infrastructural utilization and showcasing sequential operational modes during different contingencies.

Methodology: Ability to simulate state space model and control strategies in MATLAB is required.

Research Objectives:
- Show how a parallel ac-dc link topology can operate to mitigate the need of voltage regulators.
- Design a refurbished system scheme with maximum infrastructural utilization during contingencies.
- Reconfigure the system during different contingencies.
- Translate the findings to an actual distribution grid casestudy.

Collaboration with Industry: Yes

Contact details:
- PhD student: A. Shekhar, a.shekar@tudelft.nl
- TUD supervisor: L. M. Ramirez-Elizondo, l.m.ramirezelizondo@tudelft.nl; Pavol Bauer
- Industry Contact: Marko Kruithof, m.g.kruithof@tudelft.nl
MODULAR MULTILEVEL CONVERTER IN STATCOM OPERATION

Type of project: MSc thesis

Scope: This project explores the use of modular multilevel converter (MMC) for harmonic elimination. The concept is to be applied to mitigate the power quality issues and highlight the trade-offs and challenges therein. Supporting ancillary services should be technically proven.

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 converter 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.

Collaboration with Industry: No

Contact details:

- PhD student: A. Shekhar, a.shekhar@tudelf.nl; E. Kontos, e.kontos@tudelft.nl
- Supervisor: L. M. Ramirez-Elizondo, L.M.RamirezElizondo@tudelft.nl; Pavol Bauer
TESTING OF A MODULAR MULTILEVEL CONVERTER

Type of project: SIP 2

**Scope:** A working lab scaled modular multilevel converter (MMC) is to be developed and tested. Different control strategies need to be implemented.

**Problem definition:** Experiment with a 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:**
- Assemble different components and submodules to create a working lab scale MMC.
- Apply and test different pulse width modulation techniques and generate the required carrier wave to switch the submodules.
- Apply different control schemes, for instance capacitor balancing to test the proper operation of the developed MMC.

**Collaboration with Industry:** No

**Contact details:**
- PhD student: A. Shekhar, a.shekhar@tudelft.nl; E. Kontos, e.kontos@tudelft.nl
- Supervisor: L. M. Ramirez-Elizondo, L.M.RamirezElizondo@tudelft.nl; Pavol Bauer
Type of project: MSc thesis

Scope: Develop a (low-cost) stable power supply for electronics in the range of 5-10W that is powered from a 1500Volts DC source, combined with accurate current measurement.

Problem definition: More and more medium voltage DC applications are envisioned in the future, as well as existing applications in DC traction. Accurate current measurement and stable power supply for electronics, taken from a medium voltage DC source is still an industrial challenge. The power supply in the range of 5 to 10 Watt should also work during start-up and shutdown of the DC source.

Methodology: This project can include a literature study, specification, design, realisation (building) of the power supply and current measurement and verification (testing).

Research Objectives:
- Specification of power supply and current sensor
- Design of the power supply
- Realisation of a prototype
- Verification (testing) of the correct functioning

Collaboration with Industry: possible with end-customer of DNV GL

Contact details:
- Supervisor: Peter Vaessen, p.t.m.vaessen@tudelft.nl
COPPER RECOVERY FROM SUBSEA INTERCONNECTOR CABLES

Type of project: MSc thesis

Scope: Investigate the technical possibilities (and economics) to recover copper at the end of lifetime. Two aspects are to be considered, recovery from existing abandoned subsea interconnector cables and innovative methods for new cable installations to facilitate recovery.

Problem definition: For interconnector projects, there is no residual value assigned for the interconnector cable at the end of its lifetime because recovery from the seabed is too expensive compared to the value of the copper. In future, there will be more and more cables abandoned due to the increased number of projects planned and constructed, see e.g. ENTSO-E 10-year network development plan 2016.

Methodology: This project can include a literature study on feasible technologies, economic analysis and if possibly a (small) experimental test setup, advice for future directions, if any.

Research Objectives:
- Overview of technical possibilities
- Estimate of economic analysis
- Solution demonstration (proof of principle)
- Advice for future directions

Collaboration with Industry: Yes, DNVGL, collaboration with other disciplines is essential for success

Contact details:
- Supervisor: Peter Vaessen, p.t.m.vaessen@tudelft.nl
**GRID CONNECTION ENERGY HUB ISLAND**

**Type of project:** MSc thesis

**Scope:** For far offshore wind it is beneficial to transform AC current from the wind turbines to DC current, in order to reduce transport losses. For large far offshore wind farms it might become feasible to place the required HVDC converters on an artificial island instead of offshore platforms. This concept can potentially realise large cost reductions for both TSO’s and wind farm developers.

**Problem definition:** The Energy Hub Island concept raises new questions. Will cable routing be a problem for connecting all the cables to the island? Is needed to place AC substations near the wind turbines to bundle cables and reduce the number of cables to be connected to the island? The conditions on an artificial island are different than onshore. How does that effect the choice of electrical components and the functional requirements for the island?

**Methodology:** We ask you to develop several grid connection concepts to connect far offshore wind via on an artificial island and compare these with the traditional situation of using HVDC converters on offshore platforms. Model simulations can help you answering this question.

**Research Objectives:**

- Find the most economic cable layout from incoming subsea cables from the wind farm, via the island to the onshore grid connection.
- Establish the functional requirements and advantages/disadvantages of a HVDC converter system on an artificial island?

**Collaboration with Industry:** Yes, this thesis project is offered by Witteveen+Bos. At our offices in Rotterdam and Deventer you can work together with colleagues and other students that are also working on the Energy Island concept. There will also be the opportunity to contact TSO’s, wind farm developers and other stakeholders.

**Contact details:**

- Company supervisor: Emiel van Druten, emiel.van.druten@witteveenbos.com
- TUD supervisor: Pavol Bauer, p.bauer@tudelft.nl
Type of project: MSc Project.

Scope: The scope of this research project is to investigate the different pattern recognition tools that can be used for automatic recognition of insulation defects producing partial discharges under HVDC.

Problem definition: Partial discharges are commonly produced in defects in insulation systems. Due to the local enhanced electric field in the defect, small pulsed currents in the range of mA and ns are produced, the so-called partial discharges. A long term exposure of the insulation system to partial discharges accelerates the ageing mechanisms that finally lead to the final breakdown of the insulation system. Early detection of the partial discharge activity is therefore recommended, since the insulation defects can be identified and maintenance or repairing activities scheduled before breakdown occurs. In order to assess the severity of the insulation defect and evaluate the failure risk, it is needed to properly identify the type of defect. For a proper identification, pattern recognition tools need to be applied to recognize the characteristic fingerprints of each defect.

Methodology: This research covers mainly two areas. The first task is to reproduce several types of defects by means of small HVDC setups, and to obtain the characteristic fingerprints of each defect. The second task is to research and successfully apply pattern recognition algorithms that can automatically recognise the defect associated with a given fingerprint. Later on, setups with known multiple defects can be used to check the limits of the pattern recognition algorithms in more complex situations.

Research Objectives:

- To create artificial defects representative of insulation defects under HVDC.
- To obtain the fingerprints representative of each type of defect.
- To apply pattern recognition tools that are able to automatically associate a given fingerprint with a type of defect.
- To determine the robustness of the selected pattern recognition tools against multiple defects.

Collaboration with Industry: NA

Contact details:

- Supervisor: Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
PARTIAL DISCHARGE CHARACTERISTICS AND INSULATION DEFECTS OCCURRENCE IN HIGH VOLTAGE CABLE ACCESSORIES UNDER TRANSIENT OVER-VOLTAGES

Type of project: MSc Extra Project

Scope: The scope of this research project is to investigate the characteristics of partial discharges and probable insulation defects that occur in high voltage cable accessories under transient over-voltage.

Problem definition: The largest part of the failures in the cable systems are occurred in the cable accessories, and it can be expected that many failures are initiated by partial discharge activities. Therefore, investigation of partial discharges can give useful information about the conditions of cable accessories and predict the probable failures. On the other hand, transient over-voltage within the transmission network, for example the ones caused by switching operations, can increase the stress on network components such as cable accessories, which will have an impact on partial discharge activities. Thus, a study on partial discharge characteristics under transient over-voltages is needed in order to provide information for failure prediction. Moreover, the above mentioned stress caused by transients can lead to the occurrence of insulation defects during service, which may result in partial discharges and even breakdowns finally. Therefore, these kinds of insulation defects must be detected out.

Methodology: This research is focused on the electrical behaviour of cable accessories like cable joints and terminations. Therefore, practical experiments in the laboratory is strongly expected to investigate the behaviour. In addition, test specimens that is defect free as well as that with artificial representative defects must be fabricated and tested.

Research Objectives:

- Define or select some typical transient over-voltages which might occur in the transmission network of cable systems, summarize the causes of these over-voltages and their characteristic e.g. waveforms and parameters.
- To produce specimens with artificial representative defects.
- Investigate the characteristics of partial discharges with applying the selected transient over-voltages.
- Detect whether some insulation defects raise in specimens under continuously applied transient over-voltages.

Collaboration with Industry: TenneT TSO

Contact details:

- PhD student: Jiayang Wu, J.Wu-3@tudelft.nl
- Supervisor: Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
MEASURE SPACE CHARGE PHENOMENA IN LIQUID INSULATING MATERIAL (LOVISILTM)

Type of project: MSc project

Scope: The scope of this research project is to study the space charge phenomena under DC condition on Liquid insulating silicon based material and build setup for measuring these space charges. The project is carried to investigate the possibilities of using existing AC joints under DC conditions.

Problem definition: Numerous research has been carried out, towards using existing alternating current (AC) infrastructure under DC conditions. The possibility of using existing Lovink AC cable joint for DC application needs to be explored. Lovisil, developed on the basis of fluid silicones is used as insulation in the cable joints. In DC cable systems, the conductivity of insulation material varies with the electric field and temperature. Higher conductivity increases the risk of thermal runaway and electrical failure. Field inversion takes place in DC cable systems, due to the formation of space charges. Therefore, space charge behaviour needs to be studied in detail.

In DC cable systems, the conductivity of insulation material increases with the electric field and temperature. Higher conductivity increases the risk of thermal runaway and electrical failure. Field inversion takes place in DC cable systems, due to the formation of space charges. Therefore, space charge behaviour needs to be studied in detail. Space charge measurements also provide information regarding the performance and degradation of the cable joint, as space charge is highly influenced by the impurity content and/or non-uniformity of the material.

Methodology: During the research, the pulse electroacoustic method used for solid to solid interfaces needs to be adapted to the solid to liquid interface. The research will start with the research on the liquid and solid acoustic properties, followed but the needed setup modifications in order to do proper measurements on the solid-liquid interface.

The company involved in this project will provide all the material that needs to be investigated i.e. Lovisil™. A paper is expected to be co-authored by TU delft and Lovink for publishing at any reputed conference/journal (IEEE/Elsevier).

Research objectives: The important objectives of this project are:

1. Initially, use the current equipment (PEA set-up) at TU Delft to investigate the behaviour of space charges in cured Lovisil.
2. Investigate the space charge behaviour in Lovisil with different interfaces (XLPE, EPR, Silicon rubber)
3. Explore modifications/changes to the existing Test set-up to measure space charges in Liquid-solid interfaces.
4. Research on other techniques to measure space charge in liquid Lovisil.


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- Lovink supervisor: Dennis Bergsma D.Bergsma@lovink.com
**Master’s Thesis Proposal**

**Type of project:** MSc thesis

**Title:** SPACE CHARGE DEVELOPMENT IN HIGH-GRADE SILICONE BASED COMPOUND FLUID AND SOLID DIELECTRIC INTERFACES.

**Scope:** Analyse the development of space charge in fluid high-grade silicone based compound and solid dielectric interfaces. This type of interfaces can be found in specific types of HV cable joints.

**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, new and existing materials need to be designed and characterized under HVDC electric fields. Fluid silicon based compounds had been used for some time as part of the dielectric materials in AC cable joints, proving to be a reliable option. Nevertheless, for HVDC systems, the space charge phenomena needs to be furthermore analysed and understood in order to use this type of configurations in a reliable way at HVDC.

**Methodology:** The project consist in a construction of a space charge measurement setup for solid-liquid interfaces. Dielectric materials provided by the company are going to be used in the measuring experiments. Several tests are needed to characterize and evaluate the performance of this dielectric interface configuration at HVDC electric fields.

**Research Objectives:**

- Understand the space charge phenomena in dielectrics.
- Design and construction of a space charge measurement setup for solid-liquid interfaces.
- Analyse the space charge behaviour in this type of interfaces.
- Interpret and analyse the results of the measurements.

**Collaboration with Industry:** Yes, Lovink Enertech.

**Contact details:**

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- Supervisor: Dr. Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
IMPULSE TEST TIME OPTIMIZATION.

Type of project: MSc Extra Project.

Scope: The main goal is to develop the knowledge rules for lightning impulse testing of power transformers.

Problem definition: In IEC 60076-3 an information about impulse testing is given. “For liquid-immersed transformers, the test voltage is normally of negative polarity, because this reduces the risk of erratic external flashovers (air side) in the test circuit” and further on “Before an impulse of opposite polarity is applied, sufficient time should be allowed for any residual charge to dissipate and restore the initial dielectric strength in the oil/paper insulation”. Part of the transformers are tested with positive polarity as sometimes is specifically requested. Currently, after the negative polarity testing sequence is completed, a period of 1 hour is used as waiting time before the positive impulses applied. However, further research is necessary to optimize this waiting time.

Methodology: This research is focused on the electrical behaviour of transformer insulation under lighting impulses. The research will be carried out by means of theoretical simulations and small scale laboratory experiments.

Research Objectives: The goal of SMIT is to reduce the waiting time so that the testing efficiency is increased without creating the risk of breakdown. This can be done by:

- finding the minimum waiting time in relation to the transformer and its insulation parameters.
- forcing the insulation discharging and depolarization processes by short circuiting the terminals or applying other type (DC or AC with specified frequency) of voltage of low amplitude.

Which of the above options is optimal in terms of time and feasibility?
In addition, an overview of the insulation behaviour during testing and accompanying changes due to electric stress is to be made.

Collaboration with Industry: Smit Transformers

Contact details:
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- TUD supervisor: Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
AN OSCILLOSCOPE APPROACH FOR CAPACITANCE-LOSSES MEASUREMENTS ON DIELECTRIC TEST OBJECTS

Type of project: MSc thesis

Scope: To set up a measuring circuit based on an oscilloscope acquisition for the measurement of capacitance and losses of a dielectric test object.

Problem definition: Measurements of capacitance and losses are of milestone importance for the diagnosis of high voltage equipment. With the availability of modern digital instruments, those parameters can be measured with varied frequency and test voltage which gives clear insights of the insulation condition. Usually, the extent of change of these parameters with frequency and voltage is very small, thereby a high accuracy and electrical disturbance rejection is demanded from the measuring instrument particularly in field. In laboratory measurements these disturbances are often well controlled and therefore a drop in the instrument specifications is possible. An oscilloscope approach to acquire the electrical signal coming from the proper sensors is then a feasible option to measure capacitance and losses in laboratory, providing economical and practical advantages.

Methodology: The project comprises the study of circuit theory for the measurement of complex capacitance from which the values of capacitance and losses are computed. The following stage is the laboratory work where the different sensor options to measure the voltage and current signals are tested. The acquisition settings of the oscilloscope and the data processing by a GUI interface also need to be approached.

Research Objectives:

- Characterization of amplitude and phase response of different voltage dividers (capacitive and resistive) with varied voltage and frequency
- Characterization of a RC measuring impedance for the measurement of current through the test object.
- Data processing of the oscilloscope acquisitions by means of a GUI interface.

Collaboration with Industry: NA

Contact details:
- Daily supervisor: Luis Castro Heredia, l.c.castroheredia@tudelft.nl
- Supervisor: Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
DESIGN AND CONSTRUCTION OF AN ACOUSTIC PD DETECTION SYSTEM

Type of project: Extra Project

Scope: To design and construct an acoustic PD detection system and to compare it with available commercial systems.

Problem definition: Corona discharges can be initiated when overhead line insulators are contaminated and exposed to fog or bad weather condition. Corona discharges can erode the insulator surface and leave tracking. It can lower the flashover voltage and lead to failure of the insulator. Detection of sound waves produced by corona discharges is a known technique used for corona detection and is used for condition assessment of the line insulator. In this project an ultrasonic PD detection system has to be designed and constructed. Performance of the system has to be tested and compared with available electrical PD detection system.

Methodology: The project is mostly focused on designing a circuit to detect and amplify corona sound. The project involves lab work and modelling. The final product has to be tested and compared with commercial PD detection systems.

Research Objectives:

- Understanding the characteristic of acoustic signal generated by PD pulses, designing a circuit that can amplify acoustic signal generated by PD pulses, verifying the design with a circuit simulation software (PSPICE for example)
- To design and construct an acoustic PD detection system suitable for measurement of external discharges

Collaboration with Industry: No

Contact details:
- Supervisor: Dr. Mohamad Ghaffarian Niasar, M.GhaffarianNiasar@tudelft.nl
MODELLING OF LEAKAGE CURRENT ON OUTDOOR INSULATORS

Type of project: MSc thesis

Scope: The scope of this thesis is to develop a model for leakage current of polymeric insulators. The model must show the relation between discharge activity on the insulator surface and the leakage current.

Problem definition: More than 70% of overhead lines interruption are due to failure of overhead insulators. Outdoor insulator installed in a polluted environment overtime become heavily coated with dirt and other chemicals. In a bad atmospheric condition such as fog or drizzle the pollution on the surface of insulator will be dissolved in water and form a conductive layer. This conductive layer cause a leakage current to flow over the surface of the insulator. A high leakage current may lead to a surface flashover which can cause line to earth fault and therefore outage of the transmission line. Leakage current get distorted depending to the severity of contamination on the insulator surface. Understanding the behaviour of leakage current versus contamination can help development of a reliable diagnostics tool for monitoring of outdoor insulators. Correlation between corona discharges on the insulator surface and leakage current is of interest for investigation.

Methodology: The project involves both simulation and laboratory work. Partial discharge activity of contaminated insulator has to be first measured and categorized both electrically and using ultra-sonic measurement. Correlation between PD current and leakage current has to be made. A model for leakage current as a function of corona activity must be developed.

Research Objectives:

- Literature review of existing publications
- Laboratory work (Building a setup for leakage current measurement, performing electrical and acoustic PD measurement)
- Correlation between leakage current and ultra-sonic PD signals
- Development of a model for correlation between leakage current and corona activity.

Collaboration with Industry: No

Contact details:

- Supervisor: Dr. Mohamad Ghaffarian Niasar, M.ghaffarianNiasar@tudelft.nl
HIGH VOLTAGE DIODES IN HIGH VOLTAGE DC SUPPLIES FOR LINEAR ACCELERATORS

Type of project: MSc project.

Scope: The scope of this project is to investigate the behaviour of high voltage diodes as used in high voltage DC power supplies in particle accelerators.

Problem definition: Nowadays, particle accelerators are used in research, medical equipment and industrial processes. Linear accelerators are a special type of particle accelerators used in many applications. Linear accelerators are used, for instance, in ion/electron accelerator systems, ion implanters, neutron generators and accelerator mass spectrometers among others. In linear accelerators, special high voltage DC supplies are used to create high electric fields that accelerate the particle species towards high energy levels. These power supplies can reach voltage levels up to 6 MV, with ripple levels in the order of 0.006%.

Due to the demands encountered in particle accelerators, a special type of DC multipliers are used, the so called Cockcroft–Walton generator. In this topology, the high voltage diodes play an important role. Mechanical, electromagnetic and thermal constraints can limit the performance of the diodes under the working conditions. Furthermore, the high voltage diodes have to be casted in resin for mechanical reasons. The high voltage diodes casted in resin form a new component that has to be characterized under the stress conditions. Therefore, the electrical, dielectric and thermal performance has to be assessed in order to achieve the required reliability of this component.

Methodology: A scientific investigation has to be carried out to assess the performance of the high voltage diodes as used in high voltage Cockcroft–Walton DC supplies. The research starts with a finite element model to analyse and simulate the electric and thermal performance. Following the analysis of the simulation results, laboratory experiments will be done with real diodes.

Research objectives:

- To create a model for finite element method analysis.
- To reproduce by means of experiments the working conditions of the diodes.
- To assess the dielectric properties of the casted diodes.
- To assess the electrical performance of diodes.
- To investigate possible failure modes.

Collaboration/Sponsorship: High Voltage Engineering Europa B.V.

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STUDY ON THE EFFECTS OF HIGH FREQUENCY HARMONIC COMPONENTS ON THE LIFE OF INSULATING MATERIALS USED IN MEDIUM VOLTAGE CABLE JOINTS

Type of project: MSc project

Scope: The scope of this research project is to identify the harmonics that are present into Distribution network because of Renewable source of energy and study its effects on various insulation materials that are used in Medium voltage cable joints. The material that needs to be tested are; Cold shrink material (Ethylene Propylene), Heat shrink material (Polyolefin / PVC) and Lovisil™ (Liquid silicone) and Protolin (Polyurethane).

Problem definition: There is a steep increase in the addition of Renewable Energy into the Electrical Grid in the recent years. This will lead to the increase in the amount of Transients (including Harmonics) in the network. This is due to the switching in the Power Electronic Components (Converters / Inverters) which act as a nonlinear loads producing Harmonics in network. The problem of such Transients and Harmonics are even worsened by the increase in usage of power electronic drives in the industries. The problem of such High Frequency Harmonics occur mostly at the distribution voltage level in network. As a result of the High Frequency Harmonic components, ageing of the insulating materials used in the Cables and its accessories is ramped up at a faster rate than before.

There are various types of cable joints available in the market based on the installation techniques and the insulating material used. Cable Joints are known to be a weak point in a cable system since this part is worked on by tools, hand etc. Failure of the Medium Voltage cable joints can be due to the accelerated ageing of the insulating material due to HF Harmonics as an effect of increased addition of Renewable Energy into the Grid.

Methodology: The research will be carried out in the high voltage laboratory of TUD using a special high voltage amplifier with high frequency capabilities. It will be needed to design the test samples in order to be compatible with the expected transient and harmonic waveforms. Followed by the measurements, statistical analysis and materials interpretation will be done.

Research objectives:

1. To design a test setup for super imposing transient spikes on to sine wave and sample preparation.
2. To design the test samples of the insulating materials with a suitable electrode configuration.
3. To test the samples and analyse the result in terms of dielectric loss factor, partial discharges, electric breakdown, and thermal breakdown.
4. To prepare an ageing model for the insulating materials at different operating voltages and harmonics of different frequencies to research about suitable and feasible sensors to be embedded in the design.


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ELECTROSTATIC COATINGS FOR TRANSFORMERS.

**Type of project:** extra project.

**Scope:** The main goal is to compare electrostatic coatings with respect to traditional coatings used in transformers.

**Problem definition:** Electrostatic coating is a cheap and simple methodology of covering metallic part with thin layer of insulating material. There has already been some studies done [1] and it turned out that by applying a thin layer of coating, the breakdown voltage could be increased by 20 to 30% over the situation when bare electrodes are used.

The electrostatic coating seems to be an alternative for paper insulation when considering the shielding elements. This is mainly due to the time necessary to place several layers of paper on the shield. For that reason, a feasibility study over the coating application on transformer metallic parts is proposed.

**Methodology:** The investigation could be approached and split into the following steps:

1) Compare the breakdown voltage of bare and coated electrodes.
2) Make some mechanical damages to the surface of the bare electrode and the coated electrode and investigate the breakdown voltage.
3) Perform thermal ageing of the coated electrode and subject the electrodes to the AC breakdown test.

**Research Objectives:**

- What is the criterion determining the paper thickness on the metallic shield?
- What are the usual/expected distances between the shields together with the accompanying voltage difference?
- What is the performance of the bare, coated, and paper wrapped electrodes?

**Collaboration with Industry:**
Smit Transformers

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OPTIMIZATION OF THE DIELECTRIC DESIGN RULES FOR THE RADIAL SPACER WINDING.

Type of project: extra project.

Scope: The goal of the research is to determine the limits of the dielectric strength of the radial spacer winding.

Problem definition: The dielectric design rules of radial spacers have to be developed and the insulation limits have to be known for optimal transformer construction. An exemplary scheme of the radial spacer winding is shown on the left part of the figure below (a). The winding is constructed in the form of discs that are wound in the radial direction, perpendicularly to the core limb. Between subsequent discs, cooling ducts are created by inserting spacers in the radial direction. Thus, the dielectric strength is provided by the spacer (and its surface) between paper insulated cables and the oil gap between the same cables.

Methodology: The first part of the research will focus on impulse testing on arrangements of (b) and (c). To determine the limits of the dielectric strength of the radial spacer winding, dielectric withstand tests of a real winding model will be carried out. When the withstand level is found, the test is to be repeated a number of times to so that the test results can be analyzed statistically. For the testing purposes, it is proposed to prepare two types of test objects. One is in the shape of two coils of paper insulated wire separated by spacers arranged in radial direction (b). The other one will consist of two parallel wires insulated with paper and separated by spacers. An example of such arrangement can be seen on the right part of the figure above (c).

Research Objectives: The goal is to determine the electric stress limits between two coils separated by spacers as influenced by the spacer (and so the gap) and the paper insulation thickness. This is to be determined for AC voltage, full and chopped lightning impulse.

Collaboration with Industry: Smit Transformers

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DC MEASUREMENTS ON TRANSFORMER INSULATION.

Type of project: MSc / Extra Project.

Scope: The main goal is to develop the knowledge rules for measurement of the DC resistance of the insulation.

Problem definition: The DC resistance measurements of a transformer insulation are performed at several production stages, starting from core stacking up to the moment proceeding shipment and finally on-site. That means that both impregnated and non-impregnated insulation is measured (250 - 1000 V). Each time, the resistance of several insulating parts is measured (e.g. core to ground, clamping construction to ground etc.). During the measurements the insulation that is exposed to the electrical stress is polarized. This results in different value of the resistance when the polarity is reversed. Additional aspect that impedes the interpretation of the resistance measurements is the behavior of the insulation when subjected to DC stress. Due to gradual polarization and charging of the insulation, the measured DC resistance tends to increase over time (current flowing through the insulation tends to decrease). Normally, the resistance is measured after 15 seconds and later on after 1 minute from the moment the voltage is applied.

Methodology: This research is focused on the electrical behaviour of transformer insulation under DC. The research will be carried out by means of theoretical simulations and small scale laboratory experiments.

Research Objectives: Define knowledge rules on how to perform the DC resistance measurements in order to obtain consistent and representative results. Therefore, the following questions are to be answered:

- When performing the DC resistance measurements, what should be the optimal time interval between the measurements at two different polarities so that obtained results are comparable?
- Is it possible to perform measurements subsequently the measurements at two different polarities by e.g. short circuiting the terminals or applying AC voltage before the measurements? If so, what should be the duration and value of the voltage?
- What are the relevant parameters of the impregnated paper insulation that play the role in the polarization and depolarization process?
- What are the values of the DC resistance that could be expected for non-aged and dry oil-impregnated paper insulation as well as the one that is thermally degraded and has a high degree of moisture? When do we know that the insulation resistance is sufficient?

Collaboration with Industry: Smit Transformers

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ARTIFICIAL MUSCLES’ AGEING BY DIELECTRIC’S SPACE CHARGES

**Type of project:** MSc Thesis

**Scope:** Increase the current lifetime of dielectric-electroactive-polymer-based artificial muscle by giving a better understanding of their ageing and failure mechanisms. This problem can be tackled by inspection of space charge accumulation in the dielectric.

**Background:** Electroactive Polymers (EAP) drawn, lately, increasing attention by industries and scientific community due to their high potential use. Wave energy converters, muscle-like actuators, tunable optics, robotics, micro-robotics and biomimetic to mention some application fields. EAP are soft and elastic dielectrics that are used in capacitor-like actuator: when high voltage DC is applied to the opposite sides of thin EAP membrane (order of micrometers), the large Maxwell stress created makes the material compress between the electrodes and expand on their sides, generating a mechanical displacement. The displacement is proportional to the square of the applied electric field, therefore is crucial to study the effect of high voltages on EAPs.

**Problem definition:** The current main limiting factor of EAPs is their lifetime. It is believed that charge accumulation in dielectric’s defects or traps lead to local electric field enhancement and hence to failure by dielectric breakdown. This causes premature and unwanted failure of the device. Accumulation processes are well known and long studied for stiff and bulky dielectrics, but the knowledge for elastic and micrometer-sized ones is still lacking. By filling this gap, would be possible to better engineering the dielectric in order to avoid this accumulation mechanism and make the EAP last longer under usage.

**Methodology:** The student will first acquire a genuine understanding of EAP working principle and space-charge accumulation. Lately, he will dedicate mostly to set-up design, testing and measurements.

**Research Objectives:**
- Design an effective setup for suitable and repetitive tests

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- Supervisor: p.bauer@tudelft.nl
ARTIFICIAL MUSCLES’ AGEING BY DIELECTRIC’S PARTIAL DISCHARGE

**Type of project:** MSc Thesis

**Scope:** Evaluate the influence of partial discharge mechanism on the lifetime of electroactive-polymer-based artificial muscles.

**Background:** Electro-Active Polymers (EAP) drawn, lately, increasing attention by industries and scientific community due to their high potential use. Wave energy converters, muscle-like actuators, tunable optics, robotics, micro-robotics and biomimetic to mention some application fields. EAP are soft and elastic dielectrics that are used in capacitor-like actuator: when high voltage DC is applied to the opposite sides of thin EAP membrane (order of micrometers), the large Maxwell stress created makes the material compress between the electrodes and expand on their sides, generating a mechanical displacement. The displacement is proportional to the square of the applied electric field, therefore is crucial to study the effect of high voltages on EAPs.

**Problem definition:** When high electric fields are involved, small and unavoidable cavities due to imperfections or contamination of the dielectric start to breakdown (discharge), generating a very small stream of current across the electrodes. Every small discharge locally modify or disrupt the material. If this mechanism is persistent in time, the discharges will be gradually be bigger in magnitude and it will finally lead to dielectric breakdown and failure of the device. By knowing the correlation between the partial discharges and time-to-breakdown, we will be able to predict the status of ageing of a device, and hence its remaining lifetime.

**Methodology:** The student will first acquire a genuine understanding of EAP working principle and partial discharge detection. Lately, he will dedicate mostly to set-up design, testing and measurements.

**Research Objectives:**

- Design an effective setup for suitable and repetitive tests

**Contact details:**

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BREAKDOWN MECHANISM OF HIGHLY VISCIOUS DIELECTRIC LIQUID

Type of project: MSc thesis

Scope: The scope of this thesis is to model pre-breakdown phenomenon occurring in highly viscous dielectric liquids.

Problem definition: Streamer formation is the pre-breakdown mechanism in dielectric liquids. Based on the applied voltage it can be classified as positive or negative streamer. Mechanisms of breakdown is different for each of the streamer type. In the case of negative streamer, streamer is initiated due to formation of microbubbles adjacent to the needle tip. The bubble itself forms subsequence to a current pulse injected to the liquid due to an electronic avalanche. The current pulse create a high temperature zone inside the dielectric liquid which vaporizes the liquid and forms the micro bubble. The bubble would further expands and reach a maximum size. Thereforth the bubble contracts and vanishes. Due to columbic and electrophoretic forces the bubble may detach from the needle tip and float into the liquids. Current pulses recorded from the negative polarity shows a pulse train typically increasing in magnitude. The goal of the project if to simulate these complex, Multiphysics phenomenon.

Methodology: The work include initial laboratory measurement in which corona discharge on a point-plane geometry immersed in the dielectric liquid must be recorded at positive and negative voltage polarity with fast and slow detection systems. A FEM model that simulate the pre-breakdown phenomenon has to be developed.

Research Objectives:
- literature review of existing theory and publication about breakdown mechanism of dielectric liquids and simulation methods that have been used
- experimental work to record corona discharge under positive and negative polarities which slow and fast detection circuit
- Development of a FEM model that simulate the pre-breakdown phenomenon

Collaboration with Industry: No

Contact details:
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ENERGY HARVESTING FROM AC OVERHEAD TRANSMISSION LINES

Type of project: Extra project

Scope: The scope of this project is to design and construct an energy harvesting system from overhead AC transmission lines for powering monitoring and inspection equipment.

Problem definition: Inspection of overhead lines are usually done using a helicopter or by driving a car parallel to the line. Activities such as visual inspection, corona discharge measurement, thermal imaging, etc. are done during the inspection. By doing so it is possible to assess the condition of overhead line and to prevent unexpected line failure (for example by identifying contaminated line insulators it is possible to change them during a pre-planned line outage and eliminating unexpected failure). Recently man controlled drones are being used to inspect overhead lines. The drone’s battery drains after short time (~10 minutes) which means the inspection using a drone is limited. If a drone can charge itself using AC transmission line, the drone can fly parallel to the transmission line, doing the inspection, and charge itself whenever needed. A complete line inspection using drone would be then possible which is more economic than using a helicopter.

Methodology: The work involves design, modelling, construction and testing. A suitable energy harvesting system has to be designed based on the need. The designed system must be constructed and tested. The system should be tested in high voltage lab and under high voltage condition.

Research Objectives:

- Literature review of existing energy harvesting system from AC transmission line
- Design and construction of an energy harvesting system, suitable for charging a drone
- Evaluate possible challenges of the moment when the system attaches or separates from a high voltage conductor

Collaboration with Industry: No

Contact details:

- Dr. Mohamad Ghaffarian Niasar, M.GhaffarianNiasar@tudelft.nl
MODELLING OF SURFACE CHARGE DECAY ON INSULATORS IN AIR

**Type of project:** MSc thesis

**Scope:** To develop a FEM model that describes charge decay on the surface of insulator in contact with Air

**Problem definition:** Presence of surface charge on the surface of insulators can change the electric field distribution and therefore alter the performance of the high voltage apparatus. Study of surface charge decay is therefore of interest. Different parameters such as bulk conductivity, surface conductivity of the dielectric, and the surrounding gas can influence on charge decay process over the surface of dielectric. In this project surface of different insulators must be charged with corona discharge and correlation between charge decay and corona activity should be measured. A model that includes the three mechanisms of charge decay must be developed and the FEM model should be verified with the experimental work. COMSOL will be used as the simulation software.

**Methodology:** The work includes both experimental work and simulation with COMSOL.

**Research Objectives:**

- literature review of existing models and publications related to charge decay
- experimental work to measure the relation between corona activity and charge accumulation on the surface of dielectric
- Development of a FEM model that includes different charge decay mechanism and to verify experimental observations

**Collaboration with Industry:** No

**Contact details:**

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**AC LOSS MODELLING IN SUPERCONDUCTING TAPES AND CABLE**

**Type of project:** MSc thesis

![Diagram of superconducting tape](source: Marijn Pieter Oomen, PhD thesis)

**Scope:** The scope of this project is to develop a finite element model for calculating AC losses in the superconducting tape with different tape size and cable design.

**Problem definition:** Superconductors are materials that can conduct a stationary electrical current without resistance. Alternating magnetic fields and transport currents cause dissipation of energy in superconductors. The energy dissipation is called AC loss. The magnetic field penetrates the material in the form of flux lines. The magnetic-field variation inside the material induces an electric field $E$ according to Faraday’s law. The electric field drives “screening currents” in the material. The screening currents determine the magnetic-field distribution in the superconductor according to Ampere’s law. The screening currents dissipate energy given by $E.J$. The energy is delivered by the external magnetic field and is supplied by the power source which generates the magnetic field. The energy is required for depinning and moving the flux lines, which is a dissipative process. The energy is converted into heat that must be removed by the high cost and low efficiency cooling system. AC loss is therefore an undesirable phenomenon.

**Methodology:** The research is included the modelling of the cable in COMSOL Multiphysics® software and calculating the AC loss (the energy which is required for depinning and moving the flux lines).

**Research Objectives:**
- Model the superconducting cable in COMSOL Multiphysics® software.
- Calculating the AC loss and validating with the available publications.
- Reducing the AC loss by changing the configuration of the superconducting tapes.

**Collaboration with Industry:** No

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INFLUENCE OF HIGH TEMPERATURE SUPERCONDUCTING CABLE ON TRANSIENT BEHAVIOR OF POWER SYSTEM

Type of project: MSc thesis

Scope: The scope of this project is to study the transient behaviour of High Temperature Superconducting (HTS) cable in a meshed power system network.

Problem definition: HTS cables have quite a different behaviour than the standard XLPE insulated cable. In a head-tail situation the HTS cable is naturally dominant. However, the Dutch grid is a meshed system and a strongly deviant behaviour of a HTS cable may have a very significant impact on the surrounding conventional grid. This concerns both normal behaviour and special conditions (breakdown nearby the HTS cable, transients, lightning impact through nearby OHL [=overhead line]).

Methodology: The research is included the modelling of the HTS cable in power system simulator (Matlab®, EMTP® or PSCAD®) and studying the different operational condition of the network.

Research Objectives:

- < Calculating the electrical parameter of the HTS cable during the normal and transient states >
- < Simulating the different operational condition of the system including normal operation, short circuit, lightning impact through the nearby OHL, short circuit fault in nearby cable or OHL systems>
- < Providing information for protection coordination in power system >

Collaboration with Industry: No

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