Title: Magnetic Aspects of Integrating Solar Roads with Wireless Charging for Electric Vehicles

Type of project: MSc thesis

Scope: Modelling magnetic field distribution in inductive power transfer (IPT) systems for electric vehicle charging and their influence on solar roads.

Problem definition: Feasibility study of integrating wireless energy transfer technology with roads capable of generating solar power offers a possibility to look into the impact of magnetic fields and offering solutions to mitigate the issues related, particularly the reduction in mutual coupling due to eddy currents generated in the metallic back contact sheet of the solar cell.

Methodology: Develop COMSOL models to describe the magnetic field distribution while integrating solar roads with IPT technology.

Research Objectives:

- Model the magnetic field effects when (IPT) coils are integrated with solar road technology. Describe associated losses and reduction in coupling.
- Suggest possible ways to mitigate the problems arising, by reduction in unit solar cell size, change in back contact material and magnetic field redirection.
- Quantify the best solution for integration of the two cutting edge technologies by optimizing in terms of efficiency, field coupling and material weight.

Collaboration with Industry: No

Contact details:

- Researcher guides: <Soumya Bandyopadhyay, s.bandyopadhyay@tudelft.nl>
  : <Venugopal Prasanth V.Prasanth@tudelft.nl>
  : <Aditya Shekhar, a.shekhar@tudelft.nl>
- Supervisor: <Pavol Bauer, P.Bauer@tudelft.nl>
Title: Comparison of novel wind turbine generators

Type of project: MSc thesis

Scope: Novel wind turbine generators are proposed for large wind turbines (10 MW and above) or for increasing the reliability of the drive train. For large wind turbines, direct-drive superconducting generators and pseudo direct drive generators are most promising candidates. For increasing the reliability, brushless doubly-fed induction generators are being assessed. It is very interesting to compare such novel generators with each other and with the conventional types, e.g. permanent magnet generators, electrically excited generators and doubly-fed induction generators.

Problem definition: This study will compare the most promising novel wind turbine generator types with each other and with the conventional generator types. The comparison result will be able to reflect the status, trend and potential of these novel generator types.

Methodology: The comparison will involve both qualitative and quantitative studies. The qualitative study will be based on an overview of the novel and conventional generator types. The quantitative study will model the drive train and evaluate the performance. This work will not have experiments. Analytical derivations and finite element simulations will be used for modelling and calculating the generator performance.

Research Objectives:

- Overview the novel and conventional wind turbine generator types
- Model the generators and calculate their performance
- Compare the studied novel generator with each other and with the conventional generator types

Collaboration with Industry: No

Contact details:

- PhD student: Dong Liu, d.liu-1@tudelft.nl
- Supervisor: Henk Polinder, H.Polinder@tudelft.nl
Title: Achieving Better Power Transmission in HVDC Systems via a Superposed AC Voltage at Specific Frequencies.

Type of project: MSc Thesis Proposal

Scope: The scope of this project is to investigate the possibility of implementing a superposed AC voltage in HVDC power transmission to utilise full current carrying capacity and determine other benefits of simultaneous DC+AC high-voltage power transmissions.

Problem definition: The implementation of both AC and DC voltages on the same power line was suggested as far back as the 1950s. At that time, the goal was to superpose a DC voltage on a 50 Hz transmission system to increase the amount of current through the line. The main challenges at the time were the difficulties concerning power line protection and the lack of power-electronic devises to effectively control the DC voltage. Today, HVDC is being increasingly implemented in power transmission, due largely to the advances in power electronics and system control. This gives us the opportunity to research the benefits and challenges of superposing an AC voltage to a HVDC system. The main goal is to analyse the limitations of such a power transmission system, specify the optimal frequencies and voltage levels that can be used and to circumvent the so-called “new war of currents” by demonstrating the advantages that joint DC and AC transmission can offer.

Methodology: The basis for this thesis will be a thorough analysis of grid-code imposed and technical limitations of AC voltages on HVDC transmission systems. These limitations would then be overcome by calculating the optimal frequencies that can be used in a HVDC transmission or specifying modifications to the existing system to allow simultaneous AD+DC power transmission. Afterwards, simulations of superposed AC+DC power transmissions carried out on a HVDC model to demonstrate the benefits of this concept.

Research Objectives:

- To conduct a detailed survey on existing HVDC systems and its limitations with respect to AC.
- To specify the optimal frequencies that can be used in such a system.
- To suggest modification on existing HVDC systems to increase power-carrying capacity.
- To validate calculations and system benefits on simulation models.

Collaboration with Industry: No

Contact details:

- PhD student: Mladen Gagic MSc
- Supervisor: Prof. dr. J. A. Ferreira
Title: **Optimal Power Cable Selection for Multiple-Frequency and Superposed DC+AC Power Transfer for a Novel Low and Medium Voltage Smart Grid.**

Type of project: **MSc Thesis Proposal**

Scope: The scope of this project is to find or specify the optimal cable for a novel power system based on multi-frequency power transfer using an AC voltage superposed on a DC voltage.

Problem definition: A novel solution for the growing need for an intelligent power systems is being developed. This new power system utilises both an AC voltage and an DC voltage simultaneously on the same line, taking advantage of the benefits of both types of system while overcoming the drawbacks by implementing multi-frequency operations. Today, power cables are being designed and installed to transfer either exclusively DC or AC voltages at a fixed frequency. If these cables are subjected to conditions beyond their specified values the rated life-time of the cables suffers, the power cables cause system instability or get damaged. Therefore, an adequate cable has to be chosen or designed, one that can withstand both a low or medium DC voltage, high-frequency power transfer, power line communication and other features of this power system.

Methodology: The basis for this thesis will be a thorough analysis of the existing electrical cables used in low and medium voltage power systems and their limitations. Based on this analysis, an optimal power cable will be chosen and its performance in the proposed system examined via simulation, emulation or small-scale experiments. Possible improvements to the specified cables would also be explored to achieve higher efficiency and optimal operational usage in various conditions.

Research Objectives:

- To conduct a detailed survey on existing low and medium voltage power cables.
- To choose the one that in optimal based on the requirements of the new power system.
- To validate the choice via simulations and experimentations.
- To propose further improvements to achieve maximum efficiency.

Collaboration with Industry: **No**

Contact details:

- PhD student: Mladen Gagic MSc
- Supervisor: Prof. dr. J. A. Ferreira
MSc thesis: Design of soft-switching control for high efficiency PV converter

Research Objective: Design and test control scheme to implement soft switching in an interleaved boost converter (IBC) for PV applications.

Problem definition: PV inverters consist of two parts: DC/DC converter for maximum-power point tracking and DC/AC inverter to convert DC to AC power. To improve the efficiency of the DC/DC converter, it is vital to have soft switching. Soft-switching and boundary conduction mode will reduce the switching losses drastically. Secondly, to operate the converter at high efficiency over a wide power range, the interleaved converter must be operated modularly.

Methodology:

1. Analyse the operation of interleaved boost converter and sources of losses.
2. Investigate the methods of soft switching in boost converter esp. quasi-resonant valley switching for 10kW high power applications
3. Investigate techniques to operate the converter modularly to achieve high efficiency over wide output-range considering ripple, operating frequency and number of operating legs.
4. Implement the control scheme in simulation and verify its operation.
5. Design and test the control in hardware using an existing IBC setup
6. Evaluate the improvements in efficiency and the trade-offs between conduction losses and switching losses.

Necessary background: Power electronics, control, hardware testing

Collaboration with Industry: Yes (PRE B.V and ABB EV charging infrastructure)

Contact - Gautham Ram (PhD student), DCE & S group, G.R.ChandraMouli@tudelft.nl, LB 03.680
Responsible supervisor – Frans Pansier, Pavol Bauer, DCE & S group, P.Bauer@tudelft.nl
MSc thesis: Increase the grid integration limits of electric vehicles and PV panels

Research Objective: Increase the penetration levels of EV and PV in the electricity grid by charging of EV in a sustainable method by using PV arrays at workplace.

Problem definition: Large scale integration of PV and EV has adverse effects on the distribution network in the form of:

1. Under-voltage and over-voltage at feeder ends
2. Increased losses and possible overloading of cables and lines at feeder head
3. Overloading of distribution transformers.

However if the EV are locally charged directly from PV, then the grid power injection due to PV and power demand from grid due to EV are mutually solved. Workplace like office buildings are ideal places to setup such EV-PV chargers where employee cars can be charged in a sustainable way from the PV panels installed on top of building roof or parking areas.

Methodology -

1. Model the Dutch distribution network in a software package for load flow analysis
2. Perform load analysis to determine grid integration limits for connecting PV @ workplaces
3. Determine the grid violations that occur when the PV penetration levels increase
4. Similarly repeat the load flow analysis for estimating the highest possible grid integration levels for EV. What is the limiting factor for high penetration of EV?
5. Consider a scenario where EV are charged directly from PV using an EV-PV charger. Determine the combined integration limits for EV and PV using such EV-PV chargers. Determine if the grid integration limits are increased when EV charging is combined with PV generation? If so, by what margin?
6. Can smart charging techniques further increase the integration of EV-PV chargers

Necessary background – Power systems, PV systems

Collaboration with Industry: Yes (PRE B.V and ABB EV charging infrastructure)
Experimental verification for PV system and inverter optimization

Extra project/ SIP-2 project for 2-3 months

Goal -

Experimentally verify inverter optimization based on shading and installation characteristics

Information -

Simulation models have been developed in the department of Electrical Sustainable Energy to estimate the PV output power depending on:

1. PV panel characteristics
2. Shading
3. Solar irradiance (Direct & Diffused)
4. Ambient temperature and Wind velocity
5. Panel orientation (Azimuth & Tilt)

The simulation models have to be verified by measurements from a real PV installation. Based on the power output of the PV, the inverter size can be optimized based on energy and economic criteria. A focused and motivated work can lead due to a good paper publication.

Tasks to be executed -

1. Analyze two different PV setups based on their shading and orientation characteristics. Collect measurement data for two setups
2. Use Matlab models and Meteonorm software to estimate the PV output for the two setups for one year. Modify the model so that a close matching between estimated and measured data is obtained. Investigate the reasons for this mismatch.
3. Use the output power characteristics to optimize the inverter size so that a smaller inverter can be connected to a higher power rated array.
4. Evaluate the economic trade-offs between PV cost, inverter cost and energy loss/gain due to inverter optimization.

The project will involve both theoretical and hands-on practical work with PV systems.

Necessary background – PV basics, PV systems, PV lab and preferably PV technologies. For first year MSc student, completion of PV courses till the current quarter will be sufficient.

Contact - Gautham Ram (PhD student), DCE & S group, G.R.ChandraMouli@tudelft.nl, LB 03.680

Responsible supervisor – Pavol Bauer, DCE & S group, P.Bauer@tudelft.nl
Title: Linear Programming (LP) Model of Heat Network Flows

Type of project: MSc thesis

Scope:

Combined heat and power (CHP) is a technology that decreases total fuel consumption and related greenhouse gas emissions by producing both electricity and useful thermal energy from a single energy source. To optimally exploit the flexibility of CHP units, their connection to the electricity and heat networks must be adequately modeled. Although there is plenty of literature about modelling CHP units including electricity network, there is few including heat network.

Problem Definition:

Heat network flows must be modelled in a computationally efficient way, so it can be include in more computationally demanding scheduling problems, such as unit commitment (UC) (which is a mixed-integer linear problem). So, the network flows should be preferably modelled under the linear programming (LP) approach, thus avoiding high computational complications.

Methodology:

The project is about developing mathematical models and implement them as LP models, so simulations can be carried out.

Research Objectives:

- Perform a literature review about different models for optimal heating flows
- Create an LP model of heat network flows.
- Clearly assess the advantages and disadvantages of modelling heat network flows as an LP
- Couple heat network flows with an UC problem.
- Assess the economical impact of including heat network flows within UC problems.

Collaboration with Industry: No

Contact details:

- Postdoc researcher: Dr.ir. Germán Morales-España, G.A.MoralesEspana@tudelft.nl
- Supervisor: Dr.ir. Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
Title: Tight Modeling of Combined Heat and Power Units in Unit Commitment

Type of project: MSc thesis

Scope and Problem Definition:

Combined heat and power (CHP) is a technology that decreases total fuel consumption and related greenhouse gas emissions by producing both electricity and useful thermal energy from a single energy source. To optimally exploit the flexibility of CHP units, their CHP units need to be optimally scheduled in advance to adequately cover an expected electricity and thermal demands. This optimal schedule is achieved by solving the so-called unit commitment (UC) problem. However, taking into account all CHP technical operating constraints, such as minimum up/down times, start-up and shut-down procedures, make the computational problem highly demanding.

Mixed-Integer Linear Programming (MIP) has become a very popular approach to solving UC problems due to significant improvements in off-the-shelf MIP solvers. Despite the significant improvements in MIP solving, the time required to solve UC problems continues to be a critical limitation that restricts their size and scope. Nevertheless, improving an MIP formulation can dramatically reduce its computational burden and so allow the implementation of more advanced and computationally demanding problems, like optimal scheduling of CHP units.

Methodology:

The project is about developing mathematical models and implement them as MIP models, so simulations can be carried out.

Research Objectives:

- Create a tight and compact MIP model of CHP units.
- Assess the economical impact of an adequate modeling of CHP units in UC problems.

Collaboration with Industry: No

Contact details:
- Postdoc researcher: Dr.ir. Germán Morales-España, G.A.MoralesEspana@tudelft.nl
- Supervisor: Dr.ir. Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
Title: Unit Commitment with "green curtailment" of wind and solar power generation

Type of project: MSc thesis

Scope and Problem Definition

Renewable energy targets and incentive mechanisms have been adopted around the world and have been successful in promoting wind and solar development. Examples include European countries for meeting European Union (EU) 2020 targets. Most systems operators in Europe use as much renewable energy (wind and solar) as possible during the daily operation, hence renewable energy is never curtailed unless the power system is at risk. Although numerous studies have shown that not allowing curtailment reduces system flexibility and increases system operating costs, the "zero curtailment" policy remains as a dominant policy in order to reduce CO2 emissions and thus making power systems more green every time.

If curtailment is not allowed when dealing with high penetration levels of renewable energy, then conventional power plants are started up and shut down more often, which in many cases lead to higher CO2 emissions. In other words, these "green policies" can be counterproductive, in fact wind power’s effective incremental emissions can be higher than the most polluting power plant in the system. To avoid this, curtailment must be permitted in a smart and optimal way so guaranteeing that any curtailment would actually reduce CO2 emissions.

Therefore, optimal planning of power systems must now include optimal "green curtailment" of renewable resources. This can be achieved by solving the so-called unit commitment (UC) problem. The UC consists of optimal resource scheduling in electric power systems to minimize the total system operational costs, while operating the system and units within secure technical limits.

Methodology: Perform simulations and modify already available UC formulations

Research Objectives:

- Create green curtailment policies that minimize CO2 emissions through solving an UC problem.
- Build a case study where green curtailment can be optimally scheduled within a centralized-UC framework.
- Assess the economical and CO2-emissions impact of different curtailment policies on different penetration levels of renewable energy.
- Draw policy recommendations to introduce wind curtailment in electricity markets

Collaboration with Industry: No

Contact details:

- Postdoc researcher: Dr.ir. Germán Morales-España , G.A.MoralesEspana@tudelft.nl
- Supervisor: Dr.ir. Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
Title: Frequency Control Strategies to Connect Microgrids

Type of project: MSc thesis

Scope: The scope of this project is to develop control strategies to connect microgrids, where the main mean for control is the system frequency.

Problem definition: Existing microgrids (within the CSGriP project) are mainly composed by a battery, renewable generation (wind and solar) and load. The battery is used to keep the balance between generation and load, where renewable generation is controlled (curtailed) through a frequency control mechanism. The microgrid is already self-stable but control strategies need to be developed to connect different microgrids together.

Methodology: The research is based on (dynamic) simulations using Simulink or powerfactory.

Research Objectives:

Model and simulate the dynamics of microgrids including changes in operational modes such as:

- Stand-alone
- Grid-connected (Strong & Weak grids)
- Inter-cell connections

Collaboration with Industry: Alfen, Alliander, Bredenoord, DNV GL, HAN

Contact details:

- Dr. ir. Germán Morales-España, g.a.moralesespana@gmail.com
- Supervisor: Dr.ir. Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
Title: Designing High Power Density Generic Power Converter for DC Microgrid

Type of Project: MSc Thesis

Scope:

1. To design the Generic Power Electronics Converter (GPEC)
2. To optimize the transformer design (planar transformer) and to improve the soft switching performance (above 500 kHz with Cool MOS or GaN)

Problem Definition:

Studies on microgrid has simply gone too wild and it is time for a standardized approach to design commercial products. The weak nature of microgrid is studied and set as fundamental difference to the studies of bulk grid, like what is often seen in some publications by taking the same assumption as in HVDC studies, and is often misleading. A 300 W or inter-leaved 1 kW fly-back converter working at DCM/BCD mode is defined as the generic power electronic converter (GPEC), due to following reasons: the current control can be achieved at an open loop approach, easing the most difficult part of controller design; the output impedance is inherently high and can be set to an arbitrary value in the same open loop approach, making it instantly ready for power extension (paralleled at output) and also for different applications (like battery charger, voltage source, LED driver, PV module simulator, and but not limited to arc welder). High power density of 50 W/cm3 and high conversion efficiency of 97% are achieved with soft-switching of 300-500 kHz.

Methodology:

BCM Flyback with DSP assisted soft switching of 300-500 kHz is to be employed as the main hardware topology. Firmware is to be designed in modular approach, with SoC/MPPT/Droop Control as standard functions. Communication protocol is designed in a separated Master’s Thesis.

Research Objectives:

- Soft switching above 500 kHz with Cool MOS and GaN
- Power density of 50 W/in³ with natural cooling
- Current sensor-less control/Open loop approach

Contact details:

- Post Doctorate Researcher: Dr. GU Junyin, LB 03.640, j.gu@tudelft.nl
- Supervisor: J Popovic, j.popovic@tudelft.nl
Title: A Standard Approach for DC Microgrid

Type of Project: MSc Thesis

Scope:

1. To design the Power Router (pRouter) in DC microgrid
2. To design the communication protocol, both at Local Area Network (LAN) level and Network/Transmission Layer level. Both are to be implemented with Power Line Communication (PLC).

Problem Definition:

Studies on microgrid has simply gone too wild and it is time for a standardized approach to design commercial products. The weak nature of microgrid is studied and set as fundamental difference to the studies of bulk grid, like what is often seen in some publications by taking the same assumption as in HVDC studies, and is often misleading. A 300 W or inter-leaved 1 kW fly-back converter working at DCM/BCD mode is defined as the generic power electronic converter (GPEC). A 18 kW power router is defined, which provides safety disconnection with built-in electronic arc elimination circuit, as well as conventional anti-lightning protection and leakage current protection. Apart from electric functions, it also provides information functions not only for monitoring but also for electric pricing-based power flow control.

Methodology:

In a naturally weak grid of DC microgrid, power converters are only to handle the transient generation/consumption change. Energy exchange over a longer time span (usually in the scale of multiple minutes) is to be negotiated through PLC communication with other sub-networks, which are electrically connected to the DC microgrid, because no electrical measurement outside its own sub-network is practical in this application. Communication protocol, therefore is the only means for power flow control in the DC network, and monitoring the power converters is becoming a secondary task of PLC. The methodological approach is preliminary defined as a refinery of Multi-Agent Approach.

Research Objectives:

- A Hybrid protocol is to be drafted. It is a combination of Master-Slave and CSMA/CD principle.
- Pricing mechanism to be formed for power flow of the DC microgrid, which is the prime task of pRouter
- A routing algorithm shall be implemented to form a path to transfer power from remotely connected sub-network. This can be roughly understood as a simplified IP protocol equivalent.

Contact details:

- Post Doctorate Researcher: Dr. GU Junyin, LB 03.640, j.gu@tudelft.nl
- Supervisor: Prof. J.A. Ferreira, LB 03.500, j.a.ferreira@tudelft.nl
Title: Control and modelling of DC Microgrid

Type of project: MSc Thesis

Scope:

1. Build models of converters for DC microgrid
2. Build models of different DC microgrid architectures for control study

Problem definition:

The systematic models of converters for studying DC microgrid is one of the main challenges. Different kinds of models are needed for different DC microgrid behaviour studies. Control, protection, communication and market models need different approaches of modelling of DC microgrid.

Methodology:

Matlab Simulation is expected.

Research Objectives:

- Investigating DC microgrid architectures
- Identify and model different types converters for DC microgrid architectures
- Identify methods of modelling for control, protection and market models
- Create new control method of selected architecture model

Collaboration with Industry: No

Contact details:

- PhD student: T.G.Hailu, t.g.hailu@tudelft.nl
- Supervisor: Laura Ramirez, L.M.RamirezElizondo@tudelft.nl, J.A.Ferreira, J.A.Ferreira@tudelft.nl
Title: Power Line Communication for DC Microgrid

Type of project: MSc Thesis

Scope:

The use of power line communication (PLC) for control of the system dynamics in a DC microgrid is not well investigated. This project aims to have some understanding on the possibilities of using power line communication for system dynamics control of DC microgrids and nanogrids.

Problem definition:

The use of power line communication for internet, home automation and smart metering is a common practice. Moreover, steady state control communication for setting states of a source or a load is implemented using power line communications. This project investigates the possibility of using power line communication in fast control dynamics of a system either for system stability or system protection.

Methodology:

Matlab Simulation and practical testing on a testbed of DC microgrid is expected.

Research Objectives:

- Identify different types of PLC methods, PLC modems
- Investigating and designing of network impedance, cable types
- Analysis signal fidelity in the network and propose a method of improving network impedance matching
- Simulate, Build and test PLC system identified on test set up for system dynamics control

Collaboration with Industry: No

Contact details:

- PhD student: T.G.Hailu, t.g.hailu@tudelft.nl
- Supervisor: Laura Ramirez, L.M.RamirezElizondo@tudelft.nl, J.A. Ferreira, J.A.Ferreira@tudelft.nl
Title: Lifetime investigation of dielectric elastomer under HV and high mechanical stretch for artificial muscle application.

Type of project: MSc Thesis

Scope: The scope of this project is the lifetime characterization of specific elastomeric material (Dielectric Electroactive Polymer, DEAP) when both high voltage and high mechanical stresses are applied.

Background: Electroactive Polymers (EAP) have recently drawn considerable attention, because of their potential use in wave energy converters, muscle-like actuators and as a material for application in robotics and biomimetic. Its interest is primarily attributed to the electrostrictive effect that manifests in the stretching and compression of the dielectric soft polymer when a voltage is applied to the electrodes of a capacitor-like device. The available actuation/conversion, is proportional to the square of the applied electric field, therefore is crucial to study the effect of high voltages on EAPs. Limitations to this mechanism have to be found in electromechanical breakdown.

Problem definition: The operating voltage of a DEAP artificial muscle or a DEG is very close to the breakdown voltage threshold: this means that non-wanted premature failure of the operating device is likely to occur over the time, making it unusable and, furthermore, unreliable for industrial commercialization. A prediction of the lifetime of the material under stress is then needed in order to estimate the reliability of a final device. Breakdown mechanism for soft materials is a challenging research area since an appropriate model still doesn’t exist. Moreover, there is no standard defining suitable tests for dielectric elastomer based actuator (DET).

Methodology: The main goal of this research is to analyse how the breakdown voltage threshold changes by varies some extrinsic parameters like: pressure of the electrodes, pre-stretching of the membrane under test, electrode surface. These activities will be performed in the High-voltage lab and will possibly include numerical simulations.

Research Objectives:

- Understand the mechanism of electromechanical breakdown for soft material
- Design an effective setup for suitable and repetitive tests
- Characterization of the material under different mechanical and electric stress

Collaboration with Industry: NA, internal research

Contact details:

- PhD student: a.iannarelli@tudelft.nl
- Supervisor: p.bauer@tudelft.nl
**Title:** DC-DC converters for HVdc integration: Design and Control

**Type of project:** MSc thesis

**Conceptual design of an offshore dc plug.**

**Scope:** Small HVdc networks involving up to five terminals are believed to be possible with the existing technologies. However, as more point-to-point HVdc connections are proposed or are under construction, the lack of standardization in the utilized equipment and in the used voltage and power levels will eventually lead to significant problems moving towards the realization of a highly meshed North Sea Transnational Grid.

The role of an interface could be played by multi-port dc-dc converter stations which can be placed either onshore or offshore and will be able to accommodate the interconnection of HVdc projects. These multi-port converters are called dc hubs and could operate as dc "plugs". But how can these be realized?

There are two main design proposals: with and without galvanic isolation. This thesis aims at defining the application possibilities of each of the identified schemes in a multi-port design and evaluate the impact of the technology choice within a multi-terminal HVdc (MTdc) network.

**Research Objectives:**

- Perform a survey on different dc-dc converter schemes and specify the requirements of a multi-port design;
- Develop analytical mathematical models and verify them with simulation results to analyse in as much detail as possible the dynamic behaviour of the dc hub;
- Evaluate the impact of the technology choice when it comes to operation and control during normal operation within an MTdc network.

For more information and challenges contact:

**Daily advisor:** Epameinondas (Minos) Kontos, MSc., LB 03.690, e.kontos@tudelft.nl;

**Supervisor:** Dr. Ir. Pavol Bauer, LB 03.600, p.bauer@tudelft.nl.
**Title:** DC hubs as dc breakers within an MTdc network

**Type of project:** MSc thesis

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**Design of a DC hub proposed in literature.**

**Scope:** DC hubs can be defined as multi-port dc-dc converters with the ability to interconnect different HVdc systems which operate at different voltage levels, control the power on each dc line and facilitate the connection and disconnection of any dc line without affecting the operation of the grid.

Based on the last part of the afore-mentioned definition, this thesis focusses on the application of dc hubs as dc breakers within a multi-terminal dc network. MTdc voltage-source converter-based networks are vulnerable to DC faults and lack of adequate protection has proven to be a significant problem preventing them from expansion.

Several measures have been suggested in the literature, regarding design of dc breakers and control strategies for fast and reliable detection and isolation of faulty lines, and some prototype breakers have been designed (ABB, Alstom). However, breaker use is not yet extensive and the dc fault protection topic is highly challenging.

**Research Objectives:**

- Analyse the dc fault dynamics within an MTdc network including dc hubs;
- Develop analytical models to study, in as much detail as possible, the dynamic behaviour of the dc hub in case of dc contingencies and optimize their design;
- Develop a methodology for the dc fault protection of an MTdc network using dc hubs.

**For more information and challenges contact:**

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**Supervisor:** Dr. Ir. Pavol Bauer, LB 03.600, p.bauer@tudelft.nl;
Title: Loss modelling of dc breakers for HVdc applications

Type of project: Extra/SIP 2 Project

Scope: The need for a high level protection of HVDC networks has led to the research and development of a variety of DC breaker models. Breakers provide a way to isolate faulty lines and to protect the connected equipment from HVDC line faults. Many parameters, such as on-state losses and time response for fault current interruption, have to be considered and compared, before a choice of technology is made.

To evaluate the on-state losses, fast dynamic models need to be made that can be incorporated in a multi-variable optimization tool used to optimize the protection system design of an HVdc grid.

Based on the existing literature, a mathematical analysis of the losses of different dc breakers needs to be made and dynamic models need to be designed that enable the user to calculate the breakers losses under different operating conditions without the need of simulation software.

Model Requirements:

- High computational speed;
- Capture steady-state operation;
- Exclusive use of code.

For more information and challenges contact:

Daily advisor: Epameinondas (Minos) Kontos, MSc., LB 03.690, e.kontos@tudelft.nl;
Supervisor: Dr. Ir. Pavol Bauer, LB 03.600, p.bauer@tudelft.nl.
DC Microgrid Extra Project / SIP-2 Project

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 microgrid system, implementing all smartgrid features needed in future. This can then be put into standards for a universal DC distribution system.

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 with Simulink.

Teamwork

Teamwork is needed as most parts are heavily interconnected and it is important to bring the team as a whole forward. Collaboration with other master and PhD students is essential and passing on obtained knowledge is important. At the moment we have 6 students doing their master’s thesis and 2 students working on an extra project.

Topics for Extra Project / SIP-2 Project

An extra project is a very good preparation for your master’s thesis. You can get familiar with the topics and then better decide on what specifically you want to do your master’s thesis. Doing the project in part time over a longer period would allow extra flexibility (e.g. when waiting for ordered parts).

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. Especially suitable would be work on our lab setup:

- Linux computer on module as communication module for dc/dc converters
- Designing/building hardware for our lab setup
- Writing software for microcontrollers
- Communication between Linux module and microcontrollers using PMBus/i2c bus
- Programming tool chain, Simulink, Code Composer Studio, TCP/IP network flashing microcontrollers
- WiFi, IPl6WPAN, ZigBee / USB Type-C connector

If you think that this general topic is something for you, please contact:

Laurens Mackay, LB 03.690, +31 15 27 85744, L.J.Mackay@tudelft.nl

Dr. ir. Laura Ramirez-Elizondo, L.M.RamirezElizondo@tudelft.nl
Msc Thesis: DC Microgrids

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 microgrid system, implementing all smartgrid features needed in future. This can then be put into standards for a universal DC distribution system.

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 with Simulink.

Teamwork
Teamwork is needed as most parts are heavily interconnected and it is important to bring the team as a whole forward. Collaboration with other master and PhD students is essential and passing on obtained knowledge is important. At the moment we have 6 students doing their master’s thesis and 2 students working on an extra project.

Topics for Master’s Thesis
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
- Real time 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.

Consider to do an extra project as a good preparation for your master’s thesis. You can get familiar with the topics and then better decide on what specifically you want to do your master’s thesis.

If you think that this general topic is something for you, please contact:

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Dr. ir. Laura Ramirez-Elizondo, L.M.RamirezElizondo@tudelft.nl
A new building on the Delft University of Technology Campus is considered to have a DC microgrid connecting all DC appliances in the building. Some of the devices expected are 125-150 kW peak photovoltaic panels, 30 kW LED lighting and 1225 workspaces with a total power of 10-20 kW. These workspaces will be powered by USB Power Delivery over the new USB Type-C connector providing up to 100W which is sufficient for all future consumer electronics. Fast network access will be provided this way.

In this project a case study is to be made including dynamic simulations. Possible prototypes for USB Power Delivery Converters can be designed depending on the knowledge and experience of the candidate.

Various aspects regarding general protection and control of DC grids are already driven forward by other PhD and master students. Teamwork is needed as most parts are heavily interconnected and it is important to bring the team as a whole forward. Collaboration with other master and PhD students is essential and passing on obtained knowledge is important. At the moment we have 6 students doing their master’s thesis and 2 students working on an extra project.

You can consider to do an extra project as a good preparation for your master’s thesis. In this way, you can get familiar with the topics and better decide on what specifically you want to do your master’s thesis.

If you think that this topic is something for you, please contact:

Laurens Mackay, LB 03.690, +31 15 27 85744, L.J.Mackay@tudelft.nl

Dr. ir. Laura Ramirez-Elizondo, L.M.RamirezElizondo@tudelft.nl

Dr. ir. Pavol Bauer, P.Bauer@tudelft.nl
Power loss analysis and characterization for surface mounted rectifier in high frequency voltage multiplier circuits

Type of project: MSc thesis

Scope:
Analyse the power loss for surface mounted rectifier in high frequency voltage multiplier circuits. Develop the research methodology to characterize the surface mounted rectifier power loss considering the rectifier conduction & switching characteristics, rectifier junction capacitances in high frequency, and high temperature environment.

Problem definition:
The rectifier is key components for voltage multiplier circuits used for high frequency high voltage power conversion circuit. The accurate power loss analysis of rectifier in high frequency, and high temperature environment is critical for voltage multiplier circuit performance such as power efficiency, temperature rise, volume and reliability. A systematic rectifier power loss analysis and characterization methodology need to be developed for surface mounted ultra-fast recovery silicon rectifier & silicon carbide Schottky rectifier.

Methodology:
1. Theoretical analysis of voltage multiplier rectifier switching process
2. Circuit simulation & switching process modelling
3. Lab scale conceptual hardware prototype experimental validation

Research Objectives:
- Analyse the operation modes for high frequency voltage multiplier circuit
- Set up the circuit simulation model for voltage multiplier
- Develop the methodology to characterize the surface mounted rectifier power loss
- Build the lab scale conceptual prototype to validate the simulation and analytical results
- Compare the power loss performance of ultra-fast recovery silicon diode & silicon carbide Schottky diode

Collaboration with Industry: Yes, GE China

Contact details:
- PhD student: Saijun Mao, Saijun.mao@ge.com
- Supervisor: < Dr. Jelena Popovic, J.Popovic@tudelft.nl>
Title: Energy storage optimization in small scale PV systems

Type of project: MSc thesis

Scope: Trends show that in rural households of developing nations, there has been a strong proliferation of low electric loads (< 100W) powered by PV. The system design for these kind of PV systems poses a different set of technical and socio-economic challenges than what is fully understood in the west. The primary target countries are South Africa, India and Cambodia where a significant percentage (70-85%) of people have either no access or unreliable access to electricity. This project is part of a larger PhD project, supported by the Delft Global Research Fellowship, which is involved in the overall design and implementation of off-grid PV systems tailored for low income households in developing nations. Energy storage will be an integral part of this project.

Problem definition: Battery, or energy storage is an indispensable part of an off-grid PV system. Storage use and optimization is one of the most decisive factors in system cost optimization, given the high storage costs. A perfect trade off needs to be determined between battery performance and costs. This would translate to optimizing the battery performance (efficiency), size, and longevity (lifetime) and costs. This would include but not be limited to electrical modelling, thermal modelling of the battery, and overall system modelling under a variety of scenarios. Results from the investigations would not only help in optimizing storage costs, but also help in setting precedents for the requirements from the power electronics of a such a system.

Methodology: The execution of the project will constitute a good mix of extensive literature survey on PV-storage, modelling, simulations, and mathematical optimization techniques. The student will need to understand the functioning of the complete PV system, while at the same time develop a significant depth of battery knowledge.

Research Objectives:

- To investigate the best constraints on various storage parameters that optimize costs and performance under different scenarios.
- To identify the requirements from the power electronics that can enable the optimal storage functioning under all the scenarios.

Collaboration with Industry: Industrial collaboration would be largely limited to getting field inputs on existing PV based products in rural areas.

Contact details:

- PhD student: Nishant Narayan <N.S.Narayan@tudelft.nl>
- Supervisors: Laura Ramirez Elizando - <L.M.RamirezElizando@tudelft.nl>, Jelena Popovic <J.Popovic@tudelft.nl>, Pavol Bauer <P.Bauer@tudelft.nl>
Title: Maximizing successful penetration of off-grid PV systems for rural electrification

Type of project: MSc thesis

Scope: Trends show that in rural households of developing nations, there has been a strong proliferation of low electric loads (< 100W) powered by PV. The system design for these kind of PV systems poses a different set of technical and socio-economic challenges than what is fully understood in the west. The primary target countries are South Africa, India and Cambodia where a significant percentage (70-85%) of people have either no access or unreliable access to electricity. This project is part of a larger PhD project, supported by the Delft Global Research Fellowship, which is involved in the overall design and implementation of off-grid PV systems tailored for low income households in developing nations.

Problem definition: The first part is to understand the system design at a technical level, with a good grasp of the user demands for the electric loads (to help with current accepted reliability benchmarks). Additionally, there are several external factors that impact the implementation of a technology in the rural sector of the developing world. Thus, a lot of effort is needed in understanding the socio-economic landscape within these target nations. Some of the questions that may help guide the student: if the technical design were to be implemented in the intended nations, what would be the ideal business case? For example, should the design be implemented through non-profit NGOs? Or given the purchasing power of the rural populace, should there be a pay-as-you-go scheme that is cost-competitive with the ubiquitous kerosene lamps in these areas?

Methodology: The execution of the project will constitute a good mix of extensive literature survey, technology understanding, cultivating a business acumen through business case development, gaining a grasp on sustainable energy economics, and optimization techniques.

Note: This problem statement is specifically suitable for a SET student looking for a broader view on technology application in the thesis. The student will be co-supervised with a lecturer from the TPM faculty.

Research Objectives:

- To investigate the external/soft factors affect the successful penetration of solar PV in the rural households of South Africa, India and Cambodia.
- To identify the right business case so that an off-grid PV system project is financial immune to unfavourable policies and independent of subsidies

Collaboration with Industry: Industrial collaboration would be largely limited to getting field inputs on existing PV based products in rural areas. However, given the multidisciplinary nature of the problem statement, the student may need to interact with companies, NGOs, and other local stakeholders.

Contact details:

- PhD student: Nishant Narayan <N.S.Narayan@tudelft.nl>
- Supervisor: Jelena Popovic <J.Popovic@tudelft.nl>, Linda Kamp, <L.M.Kamp@tudelft.nl>
Title: High frequency flyback transformers

Type of project: MSc project

Scope:

Investigate the optimal technology for realisation of flyback transformers, that can operate it >> 500kHz, with mains isolation, for power level up to 120W,

Problem definition:

For power supplies the flyback topology are mainstream, due to its simplicity and low cost. However: the transformers exhibit also quite some leakage inductance. For high frequency this lead to problems with manufacturability and/or performance. The winding technology that is in wide spread use is for sure not suitable anymore. Some technologies for improving the coupling between primary and secondary are known, (foil windings, multilayer planar) but they exhibit quite some parasitic capacitance, reducing efficiency, and/or are detrimental for EMI. Not finding a suitable transformer technology might inhibit the use of WBG semiconductors (esp. GaN) . Goal is to gain insight into the best way to be able to increase the switching frequency. Technology for hf operation of transformers for resonant topologies like LLC, with integrated magnetics, can be investigated as well.

Methodology:

Survey of potential techniques for hf transformers with mains insulation, including parasitics
Check consequences in flyback topology, at first using simulation.
Build two different version of transformers to verify the behaviour in a real circuit

Research Objectives:

- Overview of potential technology for mains isolated flyback transformers
- Check limits of each technology, in conjunction with the optimum operation of a flyback converter using that type of transformer
- Gain knowledge on the potential for GaN (=hf operation) in this type of converters (or in other words: can the benefits of WBG semiconductors also lead to a breakthrough in low power mains isolated power supplies

Contact details:

- Supervisor: F. Pansier, f.pansier@tudelft.nl
- Supervisor: J. Popovic, j.popovic@tudelft.nl
Title: Optimal phase shift in BCM PFC circuits

Type of project: MSc Thesis

Scope:
Reduction of EMI filtering effort in PFC circuits that run in BCM mode. This mode is preferable for hf operation (e.g. with GaN switches). Comparison with CCM mode to be made.

Problem definition:
For high power 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.

A complicating factor is that a practical BCM PFC has also an idle time during which the drains voltage rings to a minimum. Has that a large impact?

Methodology:
Interference model for the interleaved stages, simulations & mathematical proof. Both for CCM and BCM

Idem for idle time between switching cycles (with idle time as a variable)

If time permits: build a prototype for verification

Research Objectives:
- optimal interleaving strategy for multiphase PFC circuits, and whether they are different for CCM and BCM.
- Assess the influence of idle time in BCM/ZVS mode
- assess what really defines the size of the EMI filters in PFC circuits.

Contact details:
- Supervisor: F. Pansier, f.pansier@tudelft.nl
- Supervisor: J. Popovic, j.popovic@tudelft.nl
Comparative research on offshore wind energy
DOT offshore power system VS conventional implementations

MSC Thesis Topic

Background
The DOT is a revolutionary concept for the conversion of offshore wind to onshore electricity. The electrical machine in a wind turbine is replaced with a much more energy dense and therefore smaller water pump. The water pump, pumps water under high pressure from the rotor to a central offshore power station. At this offshore power station a large number of water pumps are connected together to drive a large (100+ MW) electrical machine with the use of a Pelton turbine generator (https://en.wikipedia.org/wiki/Pelton_wheel).

Main advantages of DOT concept:
1. Much lighter wind turbine due to the removal of the heavy electrical machine, thereby reducing the size of the tower and foundation.
2. Removal of the expensive electrical machine per wind turbine and replacing it by one large electrical machine with tens of wind turbines.
3. Fewer moving parts thereby lowering the need for maintenance.

In other words: The underlying philosophy is that minimizing the amount of components leads to mass reduction and less maintenance.

Current standings
At this moment a 500kW DOT prototype is being assembled in Delft, including a Pelton turbine generator, see Figure 1.

Your Goal
Conduct a comparative research between the DOT concept and the current offshore wind implementation. This includes identification of and considerations on the electric design and possibilities of a DOT offshore power system (i.e. generation, transforming/converting, transmission) from the offshore Pelton turbine to the onshore power grid with a rated power of several hundreds of MWs.

Main goal of the research
- Definition of design options of a DOT offshore wind power system
- Comparative research between the DOT concept and conventional offshore wind implementation

What we expect from you
We very much believe in “learning by doing” and so you will be expected to participate under supervision in activities such as the commissioning and testing of the DOT prototype.

Contact details:
Supervisor – Henk Polinder, H.Polinder@tudelft.nl
Title: Foreign object detection in Inductive Power Transfer (IPT) systems

Type of project: MSc. thesis

Scope:
Inductive power transfer (IPT) is the process of transferring power between circuits without wired interconnects by the process of electromagnetic induction in the near-field. Magnetic fields permeate through human skin and live objects without a problem. Hence, live object heating and EMF safety regulations in the presence of magnetic field energy transfer is a major problem.

Problem definition:
Foreign object such as leaves and pieces of iron can result in local heating of these objects and in case of live objects like cats, it can result in unacceptable leakage fields. To overcome this problem, a suitable sensing system can be proposed so that the power transferred can be adjusted depending on the type of object. Here, the emphasis is both on the foreign object detection as well as the power flow control. A unique solution is to combine Capacitive Power Transfer with Inductive using Electric Field Proximity Sensing (EFPS).

Methodology:
- Perform literature study on different foreign object detection possibilities.
- Select a suitable technique considering ease of implementation and control, modularity and cost.
- Build a lab scale prototype and test its operation for both foreign object detection and power flow.

Research Objectives:
- Proximity sensing of foreign objects during power transfer.
- Power flow control and a technique to identify the type of object.

Collaboration with Industry: No

Contact details:
- PhD student: Venugopal Prasanth, v.pranth@tudelft.nl
- Supervisor: Pavol Bauer, p.bauer@tudelft.nl
Title: Self-Healing Inductive Power Roadway

Type of project: MSc. Extra Project + Thesis

Scope:
Highways of the future have to consider the large transition of vehicles to electric vehicles (EVs). In such a scenario, Wireless Inductive Power Transfer (IPT) as a solution for range extension is becoming an important technology with a very large impact. Also, material development for roads have considered the aspect of self-healing of potholes and cracks by incorporating magnetic materials on the road. This is a challenging interdisciplinary project involving power electronics and electromagnetics.

Problem definition:
This project involves the design and development of an innovative power electronics converter technology for a concurrent Inductive Power Transfer and ‘healing’ system to be used in future roads.

Methodology:
- Develop the theoretical model and FEM analysis (COMSOL) for the system.
- Suggest techniques for magnetic field shaping and identify loopholes and use power electronics to fix problems.
- Use power electronics for a combined solution to inductive power transfer and induction heating.
- Optimize the system for IPT under normal operations and Induction Healing when required.

Research Objectives:
- Technical feasibility analysis of the system and identification of potential problems and loopholes.
- Development of power electronics and system for the sample of self-healing concrete and IPT system.

Contact details:
- PhD student: Venugopal Prasanth, v.prasanth@tudelft.nl
- Post-Doc: Dr. Peter van Duijzen, P.J.vanDuijsen@tudelft.nl
- Supervisor: Pavol Bauer, p.bauer@tudelft.nl
Title: Applicability of Vortex Bladeless in a DC microgrid for Electric Mobility

Type of project: MSc Thesis

Scope:
Non-rotational wind power extraction on the basis of mechanical resonance is the basis of wind vortex technology. Vortex is a wind generator without blades. Instead of capturing energy via the rotational motion of a turbine, the Vortex takes advantage of what’s known as vorticity, an aerodynamic effect that occurs when wind breaks against a solid structure (Kármán vortex street). The Vortex structure starts to oscillate, and captures the energy that is produced.

http://www.vortexbladeless.com/home.php

Problem definition:
This project involves the design and development of an innovative wind energy technology that can define the next generation DC microgrid both in rural electrification as well for E-mobility.

Methodology:
- Develop the applicability of Vortex bladeless for a microgrid.
- Consider a holistic comparison of wind technologies- blades and bladeless.
- Several comparison parameters like manufacturing, operating and maintenance costs, carbon footprint reduction, output power, efficiency, area for placements.

Research Objectives:
- Technical feasibility analysis of the wind vortex and mechanical resonant systems and identification of potential problems and loopholes.
- Analyse how the electric grid and mobility be affected by this technology.

Contact details:
- PhD student: Venugopal Prasanth, v.prasanth@tudelft.nl
- Supervisor: Dr. Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
- Supervisor: Pavol Bauer, p.bauer@tudelft.nl
Title: Autonomic power sensor (MSc thesis)  
Scope: Design of a wireless self-powered power sensor.

Background: Due to increasing distributed electricity generation (PV systems) and higher consumer peak loads (electric cars) the operation of the power grid becomes more and more complicated. In the future the main challenge will be to get the right energy at the right location at the right moment. This will, and already has, lead to an increasing demand in the monitoring and controlling of electricity. In general the high voltage grid is well monitored, but currently the medium and low voltage grid monitoring is limited or not even present at all. A retro fit application is therefore very desirable for two reasons:
1. In the existing distribution grid station space is limited and mounting and installing of a power measuring system with all the wiring is complicated.
2. The mounting and monitoring of a big amount of sensors in the classical way is a time consuming business.

A sensor based on an instrument transformer that operates autonomic without the need of physical wiring, is therefore very desirable.

Your goal: Proof of concept of a sensor with the following key features:
1. Self-powered by means of energy harvesting from the measured object
2. Voltage/current measurements (the core business of ELEQ)
3. The measuring signal directly converted into a digital signal inside the sensor
4. Operation as a local measuring system or in a smart grid by means of wireless communication.

Design Conditions: The sensor will be connected to the low voltage transmission line. In most cases the line is insulated. The insulation shall not be removed or altered. Design of hardware and implementation of control and communication in a lab setup.

Research Objectives:
- Wireless energy harvesting
- AC current and power measurement
- Data digitalization
- Creating a gateway to the Internet of Things specified depending on progress of the master student.

Collaboration with Industry: ELEQ BV, Steenwijk

Contact details:
- ELEQ: Ealse Noordmans, ealse.noordmans@eleq.com
- TU Delft: Venugopal Prasanth, v.pranath@tudelft.nl & Prof. Pavol Bauer p.bauer@tudelft.nl
Title: Development of a measuring system for partial discharge measurements in HVAC and HVDC tests.

Type of project: MSc Extra Project.

Scope: The scope of this research project is to develop a measuring system for partial discharge measurements in AC and DC high voltage laboratory tests.

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 leads 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.

Nowadays there is no commercial available equipment that can be used to analyse partial discharges under DC conditions. Data post processing is crucial in both AC and DC measurements. Clustering techniques are mandatory for noise filtering and noise identification. Furthermore, data post processing is needed to properly create fingerprints that are used for pattern recognition purposes in both AC and DC situations.

Methodology: This research is focused on the creation of a software for a partial discharge measuring system based on oscilloscope cards. The first task is to properly design a software to control several oscilloscope cards. Secondly, algorithms for noise identification, filters and pulse clustering techniques should be implemented in the software. After that, specific software for AC and DC should be developed. Different algorithms should be included in the software in order to create fingerprints of different type of defects. Finally, pattern recognition tools have to be included in the software for automated recognition of defects under HVAC and HVDC conditions. Software validation will be done by means of experiments in the High Voltage Laboratory.

Research Objectives:

- To create a software for partial discharge measurements in HVDC and HVAC.
- To control several oscilloscope cards for partial discharge measurements and synchronization of discharges.
- To develop algorithms for filter implementation and noise identification and cluster formation.
- To create algorithms to obtain proper fingerprints representative of different types of defects under HVDC and HVAC conditions.
- 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
Title: Pattern recognition of partial discharges under HVDC.

Type of project: MSc Extra 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 leads 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
Title: Refurbishing AC cables to operate under DC conditions for medium voltage distribution grids

Type of project: MSc thesis

Scope: Refurbishing existing AC cables to operate under DC conditions may enhance the power transfer capacity of point to point links in distribution grids using the existing infrastructure. The associated technical aspects that may arise must be explored.

Problem definition: The electric field stress on the surrounding cable insulation differs under AC and DC conditions, operating temperature and configuration (unipolar/bipolar). Detailed analysis of field stress under loaded and unloaded DC conditions must be carried out.

Methodology: This research primarily concerns theoretical description of electric field under different operational conditions on simulation platform.

Research Objectives:

- Literature review on cable types under operation in MV distribution grids and compiling list of specifications.
- Modelling the electric stress on insulation when ac cables are refurbished to operate under dc conditions. Highlight differences in field distribution with temperature.
- Highlighting the differences in field distribution for unipolar and bipolar operation.

Collaboration with Industry: No

Contact details:

- PhD student: <Aditya Shekhar, a.shekhar@tudelft.nl>
- Supervisor: <Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl>
Title: Mitigation of Geo-magnetically induced Currents in Future Power Grids

Type of project: MSc thesis

Scope: Geo-magnetically induced currents (GIC) circulate between neutral grounded star connected transformers on power transformers. Being quasi-dc in nature, these can lead to saturation, high reactive power demand, voltage instability and cascade tripping in ac power grids. The project looks into the effects and mitigation of GIC in evolving future grids.

Problem definition: Operation of power electronic converters of different topologies (CSC, VSC) with raised earth surface potential during solar storms is to be studied. The role of dc links in existing ac distribution grids in mitigating the effects of GIC is to be explored.

Methodology: In depth analysis of effects of GIC on the ac distribution grid components (power transformers, SVCs, relays, etc). Identifying the different mitigation techniques that can be employed. Modelling and simulation of interconnected dc links and converters under similar conditions is to be explored.

Research Objectives:

- Review and identify the factors involved in the phenomenon of geo-magnetically induced currents in ac power grids during solar storms.
- Describe the effects of GIC on different grid components and depicting the contingencies, existing mitigation techniques and limitations thereof.
- Model the operation of converters in such a scenario and explore the possibility of mitigating the effects of GIC with this technology.

Collaboration with Industry: No

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- PhD student: <Aditya Shekhar, a.shekhar@tudelft.nl>
- Supervisor: <Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl>
- Supervisor: <Pavol Bauer, P.Bauer@tudelft.nl>
Title: Experimental Validation of Load Side Detection Scheme for Series Arcs in DC Microgrids

Type of project: MSc thesis

Scope: In dc microgrids, arcs do not extinguish as easily as ac ones due to the absence of current zero-crossing. This demands a rapid protective response in detecting and eliminating any arcs that may arise. The proposed scheme detects the electrode dependant load side voltage drop associated with series arcing during unintended energized unplugging of loads in residential areas.

Problem definition: Development and validation of an algorithm to detect and eliminate series arcs from load side power electronics and achieving insensitivity to low frequency grid side voltage fluctuations.

Methodology: Both simulation and experimental validation of the proposed scheme is to be accomplished. The project involves programming the microcontroller and development of different test setups to depict the reliability, selectivity and sensitivity of the algorithm to different threshold voltages.

Research Objectives:

- Depict by simulation selectivity and localized action of the proposed algorithm to detect and eliminate series arc.
- Develop experimental setups to show the sensitivity and selectivity of the algorithm to generated arcs.
- Validate experimentally the insensitivity of the algorithm to low frequency grid side voltage fluctuations.

Collaboration with Industry: No

Contact details:

- PhD student: <Aditya Shekhar, a.shekhar@tudelft.nl>, Laurens Mackay, l.j.mackay@tudelft.nl
- Supervisor: <Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl>
- Supervisor: <Pavol Bauer, P.Bauer@tudelft.nl>
Title: Very high frequency power conversion (>10MHz) for LED drivers with GaN devices

Type of project: MSc thesis

Scope: The goal of this challenging project is to investigate suitable circuit topologies and operating modes for GaN-HEMT based very high frequency power conversion. Topologies are to be evaluated with respect to power loss/efficiency, loss distribution between active and passive devices, complexity, system integration, gate driving etc. This includes topologies inherited from switched mode RF power amplifiers and more conventional power electronics resonant topologies.

Problem definition:
Due to their fast switching and low losses GaN power semiconductor technology offers great potential in power electronics in terms of efficiency increase, miniaturisation and new applications. LED lighting has a potential to be a very suitable application for performance increase due to GaN and push necessary market adoption of GaN.

Methodology:
The project will include review and assessment of suitable topologies, design of the most promising candidate through model development and simulations and practical implementation on a hardware demonstrator.

Research Objectives:
- Review of topologies suitable for very high frequency conversion
- Analysis of the most suitable topologies
- Demonstrator design in the chosen topology including issues such as gate drivers, layout etc.

Collaboration with Industry: Yes, Philips Lighting.

Contact details:
- PhD student: Ainiel Shri, a.shri@tudelft.nl
- Supervisor: Jelena Popovic, j.popovic@tudelft.nl
Title: Environmental Footprint of Power Electronic Converters

Type of project: Extra Project/ SIP 2

Scope:

Power Electronic Converters (PEC) are essential for connecting Renewable Energy Sources (RES) to the power grid. However, during the design phase of these converters, Life Cycle Assessment (LCA) parameters are often neglected. Because of this, it is almost impossible to get a clear insight into contribution of PEC to the sustainability aspect of RES.

Methodology:

The goal of this project is to develop a tool to determine LCA parameters of any given PEC. In order to do so, the student is required to design an approach and implementation of LCA for PEC. In addition to that, the student should also gather data in order to build a database with LCA parameters of several PECs.

Research Objectives:

- Develop an approach/algorithim for LCA of converters
- Write an application/script that calculates LCA parameters of converters based on user input
- Create an extendable database with LCA parameters of several converters

Collaboration with Industry: No

Contact details:

- PhD student: Aniel Shri <a.s.shri@tudelft.nl>
- Supervisor: Jelena Popovic <J.Popovic@tudelft.nl>
Title: Topics in Fault Tolerance in Wind Turbine Generator Systems

Type of project: MSc thesis

Background

Even though the reliability of wind turbines has improved over time, they still see failure rates of more than one failure per turbine per year. Of these failures, the drivetrain is a source of problem and fails often. It is evident that addressing the failure rates of the drivetrain could have a major impact on the overall availability, and hence the Cost of Energy, of the wind turbine.

Fault tolerance is an important method to address the availability improvement of turbines. Here, the system is designed such that it can continue operation with a fault either at rated or reduced power levels.

The topics here are meant to give an idea of the possible scope of work for an MSc thesis in the topic – ‘Fault Tolerance in Wind Turbine Generator Systems’.

Problem definition

This topic looks at generator topologies and control strategies to make the wind turbine generator systems tolerant to faults in the windings and power electronic converters.

Methodology

These topics would include analytical machine modelling, finite element modelling and practical work depending on the aspects that the MSc thesis addresses.

Possible Areas of Work

- Design and Control of Poly-phase machines as fault tolerant machines.
- Design of modular generators and the effects of this modularity on their availability.
- Investigation on the use of cascaded machines to improve reliability.
- Generator designs used with multilevel inverters for fault tolerance.

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Title: 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:

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- **Supervisor:** Dr. Ir. Pavol Bauer, LB 03.600, [p.bauer@tudelft.nl](mailto:p.bauer@tudelft.nl)
Title: Design of a 350kW power electronics for high speed PM generator – Steam Expander

Type of project: Msc

Scope: Design of a 350kW power electronics rectifier, conceptual study

Problem definition: For coupling a high-speed permanent magnet motor / generator to the public network grid, a power electronics converter/ passive rectifier system has to be designed.

Methodology: The primary function of the generator is delivering energy to the grid, motor operation is required for the start-up of the installation.

- Passive rectification instead of the current active rectification by means of the selfcontrolled current converter,
- Integration of a motor-starter,
- Design of a new winding diagram for the generator to comply with passive rectification
- Control of the generator by means of the passive rectifier.

Research Objectives: This project aims at performing a conceptual study to connect a high speed PM generator to the grid.

- Investigation of the current electrical system
- Conceptual study to replace the existing electric system by a passive rectifier and starter-inverter.
- New design of the winding diagram for the generator, to comply with the passive rectification and to allow motor-start.
- Design study, simulation study, prototype (scale-model)

Collaboration with Industry: INNECS / Ter Aar.

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- Supervisor: Dr. Ir. Pavol Bauer, LB 03.600, p.bauer@tudelft.nl
Title: Solar eBike Charging Station

*Power Management, Mobile Interfacing, and Embedded Control*

**Type of project** Extra Project / SIP-2 Project

**Scope:** Power management for a stand-alone solar powered eBike charging station which is power neutral has to be developed. It is able to store solar power and charge up to 4 electric bikes and a single scooter. The eBike charging station should operate autonomous and be sustainable.

**Problem definition:** Design and implement a power management systems. The design covers autonomous operation, control of load sharing in the station, logging of measurement, mobile interface with the end user and communication for supervision and control.

**Methodology:** Power management and interfacing to the end-user are two important aspects that have to be implemented using a variety of tools.

- A single board PC will coordinate all communication with the controllers and hardware in the eBike charging station. Its tasks will be supervising the power management, communication with the microcontrollers, logging measurement results and visualize them via a web-based interface and finally communicate to the end-user via a wireless connection to mobile devices such as a phone or tablet.
- NXP-microcontrollers will be used to control the chargers and communication with the single board PC.
- The MODBUS protocol is used to communicate internally to the solar-tracking system and the internal battery storage as well as the grid connection. And weather station.
- A mobile App has to be developed for the end-user that communicates with the single board PC via internet.

**Research Objectives:** This project aims at programming at various levels and interconnecting these tools.

- Develop a methodology for load sharing and power management to optimize the use of the solar power.
- Improving a web-based interface for communicating with the end-user as well as supervisor-entry for maintenance of the system. Design of a mobile App for the end-user.
- Development of the tools and implementation with interfacing between the tools. (Programming both microcontrollers in embedded C and single board PC in C/C++)

**Collaboration with Industry:** No

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Title: Design a Single PV-Battery Integrated Module Prototype for Residential Applications

Type of project: Extra Project/ SIP 2

Fig 1. PV-Battery Integrated Module

Scope: Even though batteries have been considered appropriate as an electrical energy storage solution for the residential market, more research is needed to reduce the implementation costs. In order to decrease the initial costs and the complexity of PV-Battery normal installations, a physical integration is proposed [1]. A single PV-Battery Integrated Module, could result in a more convenient scheme to get the maximum benefits from PV generation. The package includes a suitable battery, dc/dc converter with maximum power point tracker, dc/ac microinverter (optional), and charge controller performing intelligent power management. All the components operate as a compact unit at the back side of the PV module.

Problem definition: Due to the fact that a single PV-Battery is a novel concept, a prototype to evaluate its functioning under experimental conditions is needed. The aim of this first project is take in consideration all the possible variables that could constrain the construction of a PV-Battery Integrated Module prototype, in order to present a design that will be implement in further steps.

Methodology: The available space for the battery, the heat management, the shape of the battery, the capacity of the batteries, and the size of the converter and micro inverter should be taken into account in the design process.

Research Objectives:

- Set the constraints to design and build a single PV-Battery Integrated Module.
- Present a electrical and spatial design for a PV-Battery Integrated Module

Collaboration with Industry: No

Contact details:

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Title: Design and Optimization of a High frequency CCM PFC Boost Converter Using Gallium Nitride Transistors

Type of project: MSc thesis

Scope:
High frequency power conversion is an ongoing trend in power electronics. Power converters operating at greatly increased switching frequencies could result in largely reduced volume of passive components, and thus high power density can be achieved. To realize high frequency operation while maintaining high efficiency, suitable power semiconductors are needed. The emerging wide bandgap semiconductors are promising candidates for fulfilling the needs.

Problem definition:
The market-available wide bandgap semiconductors, such as Gallium Nitride (GaN) power transistors and Silicon Carbide (SiC) Schottky diodes, provide potentials for improved performance in a Continuous Conduction Mode (CCM) PFC boost converter: GaN transistors enable very high switching speed, which could largely reduce switching losses even in hard switching conditions; SiC Schottky diodes do not show reverse recovery behaviour, and thus no reverse recovery loss will occur in transistor and EMI performance is improved.

This thesis will focus on optimal design and implementation of a high frequency CCM PFC boost converter for highest possible efficiency utilizing the available GaN transistors and SiC diodes.

Methodology:
Performance of GaN power transistors need to be studied firstly to explore limitations of the transistors in a CCM PFC boost converter environment, which can be done with loss models and measurement results available in the group; then, optimal design of the converter should be carried out with the converter efficiency as the goal; finally, an experimental setup should be built.

Research Objectives:
- To investigate performances of GaN transistors in CCM PFC boost converter
- To perform an optimal design of a high frequency CCM PFC boost converter
- To demonstrate the design experimentally

Contact details:
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Title: Prediction and validation of core losses in Brushless Doubly-Fed Induction Machine

Type of project: MSc thesis

Scope: The brushless doubly-fed induction machine (BDFIM) has an attractive potential to be a new variable speed wind generator due to its higher reliability and increased fault handing capabilities. However, the undesirable spatial harmonics in the air-gap magnetic field result in a bigger core losses comparing with the normal doubly-fed induction generator (DGIG). The core losses calculation is more complex because there are two stator windings with different pole-pair numbers in BDFIM. Therefore, it is important to develop an appropriate model for the prediction of the core losses and validate it in a small-scale prototype during the design of the BDFIM.

Problem definition: How to predict the core losses of the BDFIM and how to measure them in the prototype.

Methodology: Finite element (FE) model can be performed for an accurate calculation of the distribution of the magnetic field, as well as the core losses. Laboratory work on the prototype will be involved for the validation of the model.

Research Objectives:

- Literature survey on the modelling and the validation of core losses.
- Build an appropriate FE model for the core loss prediction of the BDFIM.
- Develop a way to measure the stator and the rotor core losses in BDFIM.

Collaboration with Industry: No.

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Title: 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 cable systems occur in the cable accessories, many of which are initiated by partial discharge activities. Therefore, investigation of partial discharges can give useful information about the conditions of cable accessories and predict probable failures. On the other hand, transient over-voltage within the network, for example switching surges, can increase the stress on network components like 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. 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:

- To define or select some typical transient over-voltages which might occur in the cable transmission network, summarize the causes of these over-voltages and their characteristic.
- To produce specimens with artificial representative defects.
- To investigate the characteristics of partial discharges with applying the selected transient over-voltages.
- To detect whether some insulation defects raise in specimens under continuously applied transient over-voltages.

Collaboration with Industry: TenneT TSO

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