OPERATING MEDIUM VOLTAGE AC CABLES IN DC CONDITIONS

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 COMSOL simulation platform. Experiments maybe possible.

Research Objectives:
- Literature review on cable types under operation in MV distribution grids and compiling list of specifications.
- Modelling the electric stress on insulation 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 Advisor: Aditya Shekhar, a.shekhar@tudelft.nl
- Supervisor: Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
  Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
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**FLEXIBLE DC LINKS IN AC DISTRIBUTION GRIDS**

**Type of project:** MSc thesis

**Scope:** Design of a flexible point to point dc link backbone with various control functionalities in a predominantly ac distribution grid.

**Problem definition:** Front and back converters of appropriate topology must be modelled and interfaced with the ac grid in the most efficient manner. Consider that the operating voltage at the dc side maybe higher than the ac side. Impart control strategies to obtain flexibility, redundancies and protection towards contingent faults.

**Methodology:** The study would include literature review, modelling and computations.

**Research Objectives:**
- Identify the appropriate converter topology for interfacing with ac grid.
- Model and control the dc link and obtain functionalities corresponding to power quality, harmonic elimination, voltage support, fault ride through, redundancies, etc.
- Justify whether dc link has a benefit over an ac interconnection.

**Collaboration with Industry:** No

**Contact details:**
- PhD Advisor: Aditya Shekhar, a.shekhar@tudelft.nl
- Supervisor: Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
- Supervisor: Pavol Bauer, P.Bauer@tudelft.nl
DC MICROGRID PROJECTS À LA CARTE

Type of project: Extra Project / SIP 2

Scope: We have plenty of things that can be done in our lab setup. If you would be interested or have some specific ideas, please tell us.

Problem definition: Nowadays most electric loads 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 reasonable look into using DC to connect all these DC sources and loads. Our research focuses on finding the “optimal” low voltage DC microgrid system, implementing all smartgrid features needed in future. This can then be put into standards for an universal DC distribution system. We are building a real DC lab to verify our findings. As the usual voltages are 350 V – 400 V we can build it 1:1. The lab grid will consist of a number of DC/DC converters that will emulate typical sources and loads.

Methodology: These projects can include simulations, design of hardware and implementation of control and communication in our lab setup.

Research Objectives:
- Hardware
- Communication between Linux computer on module and microcontrollers using i2c bus
- TCP/IP communication to Matlab Simulink on a host computer.
- Programming, Simulink, Code Composer Studio, TCP/IP network, flashing microcontrollers.
- Control framework templates for C2000 microcontrollers.
- Optional would be the addition of WiFi, IPLo6WPAN, ZigBee networks.
- We are open for other ideas.

Collaboration with Industry: Possible. Collaboration with other master and PhD Advisors in the DC microgrid team is essential for success

Contact details:
- PhD Advisor: Laurens Mackay, L.J.Mackay@tudelft.nl
- Supervisor: Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
MULTIPURPOSE DC-DC CONVERTER FOR DC DISTRIBUTION GRID APPLICATIONS

Type of project: MSc Thesis

Scope: Designing DC/DC converters for use in DC microgrids.

Problem definition: Nowadays most electric loads 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 reasonable look into using DC to connect all these DC sources and loads. Our research focusses on finding the “optimal” low voltage DC microgrid system, implementing all smart grid features needed in future. This can then be put into standards for an universal DC distribution system. We are building a real DC lab to verify our findings. As the usual voltages are 350 V – 400 V we can build it 1:1. The lab grid will consist of a number of DC/DC converters that will emulate typical sources and loads.

Research Objectives:
- Bidirectional DC/DC converters for DC microgrids.
- Grid connection, inrush current limiter, black start of the grid.

Collaboration with Industry: Collaboration with other master and PhD Advisors in the DC microgrid team is essential for success.

Contact details:
- PhD Advisors: Juan Pablo Rivera Barrera J.P.RiveraBarrera@tudelft.nl, Laurens Mackay L.J.Mackay@tudelft.nl
- Supervisor: Laura Ramirez Elizondo L.M.RamirezElizondo@tudelft.nl
INTERCONNECTING SOLAR HOME SYSTEMS IN DEVELOPING NATIONS

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: Interconnecting SHS into a DC grid requires a marked shift in technical design mindset, as the implementation space involves developing communities with various needs that add a different set of constraints and challenges. Most of the household electrical appliances are low voltage, and very efficient (a recent trend). Both power sharing between households, and resource sharing in terms of the distribution lines, cables, interfacing converters, etc. need to be reformulated in this context. The pricing mechanisms would also need to be redesigned that enable judicious demand side management and efficient storage utilization.

Methodology: First a literature study has to be made. Typical applications and power demands and demand response potential in rural communities have to be assessed. Pre-existing steady state power flow simulation has to be further developed this includes optimal power flow and dynamic pricing. Market models have to investigated and suitable business models derived. Phases of evolution towards a full dc distribution grids should be identified and simulated.

Research Objectives:
- To develop a viable path for going from disconnected SHS to interconnected (off-grid) LVDC distribution smart grid.
- To investigate the preferred grid topologies (choice of distribution lines, cable thicknesses, and converters)
- To determine the market models that would enable power and resource sharing.

Collaboration with Industry: Possible collaboration with field researchers to get active relevant data from communities in developing nations.

Contact details:
- PhD Advisors: Nishant Narayan, N.S.Narayan@tudelft.nl
  Laurens Mackay, L.J.Mackay@tudelft.nl
- Supervisors: Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
ALL DIGITAL LOAD LOSS REFERENCE – SENSITIVITY, STABILITY, AND EFFECT OF QUANTIZATION ON PHASE UNCERTAINTY OF SYNTHESIZED CURRENT

Type of project: MSc thesis

Scope: Calibration of equipment for loss measurement (power analysers) in power transformers and inductors is carried out by means of phantom power source. Voltage terminals of the power analyser are connected to a voltage reference, while current is supplied to a current terminal from a very accurate and stable current source. Knowing parameters of the current and voltage waveforms and comparing the reference power to power measured by the power analyser, a calibration of power analyser is performed. The device for synthesis of the current waveform is known as a phantom power source. Eco design directive of EU puts more stringent requirements on loss measurement in power transformers and reactors. Future regulations require measurement uncertainty of less than 5% in power measurement for large high-voltage transformers. This translates to phase uncertainty measurement better than 20urad at low power factors (p.f. 0.01). This imposes strict requirements on the phantom power source in terms of uncertainty of phase of generated current.

Problem definition: Digital realization of the proposed phantom power brings more flexibility. A digital control algorithm based on accurate phase locking is simulated, with satisfactory results. Several adaptive algorithms for phase and frequency update are also investigated. For considered digital control algorithms investigate the effects of the following on the phase uncertainty of synthesized current and system stability:
- Input signal quantization and finite word length
- Effect of jitter in the clock frequency of the ADC and DAC converters
- Variation in reference voltage frequency
- Quantization of digital system parameters

Methodology: Analytical model should be developed and verified by means of simulation in Simulink or similar suitable software (e.g. spice).

Research Objectives:
- Sensitivity analysis.
- Stability analysis.

Collaboration with Industry: VSL Dutch Institute for Metrology

Contact details:
- PhD Advisor: Mladen Gagic, M.Gagic@tudelft.nl
- Supervisor: Prof. Bram Ferreira, J.A.Ferreira@tudelft.nl
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 devices 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 Advisor: Mladen Gagic, M.Gagic@tudelft.nl
- Supervisor: Prof. Bram Ferreira, J.A.Ferreira@tudelft.nl
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 Advisor: Mladen Gagic, M.Gagic@tudelft.nl
- Supervisor: Prof. Bram Ferreira, J.A.Ferreira@tudelft.nl
AUTONOMIC POWER SENSOR

Type of project: Internship

Scope: Design of a wireless self-powered power sensor. ELEQ is a leading designer and manufacturer of smart electrotechnical applications for protecting, measuring, transportation, and connecting electrical energy. ELEQ works worldwide with renowned companies in electric power sector, along with system builders and installers.

Background: A concept of a self-powered wireless current sensor has been in the development in the form of a thesis, which is a great leap in the field of current measurement. This concept has to be developed into a working prototype along with its supporting system.

Your Tasks and Responsibilities:
- Develop a working prototype based on the MSc thesis.
- Investigate into smart grid solutions.
- Give directions in internet of things applications.
- Give directions in industry 4.0 applications.

Skills and Qualifications:
- Enrolled in a MSc/ BSc programme.
- Understanding of analogue and digital electronics.
- Experience with embedded coding (TI’s environment is an advantage).

Behavioural Competencies:
- Strong communicator and a team player.
- Punctual.
- Desire to do new things.

Collaboration with Industry: ELEQ BV, Steenwijk

Contact details:
- ELEQ: Ealse Noordmans, ealse.noordmans@eleq.com
  Neal Chaudhuri, neal.chaudhuri@eleq.com
- TU Delft: Prof.Dr. Eng. Pavol Bauer; P.Bauer@tudelft.nl
  Venugopal Prasanth, v.prasanth@tudelft.nl
Type of project: MSc Thesis

**Scope:** The scope of this project is to study how the reliability of a general electroactive polymer, used for Artificial Muscle applications, can be improved by better understanding the mechanisms that cause the breakdown of this material. Two main mechanisms will be investigated: Electromechanical (EMI)-induced breakdown and defects-induced breakdown.

**Background:** Dielectric Electroactive Polymers (DEAP or simply EAP) have recently drawn considerable attention, because of their potential use in wave energy converters (DEG), muscle-like actuators (Artificial Muscles) and as a material for application in robotics and biomimetic. When a film of this soft polymer is coated both sides with compliant electrodes and a differential voltage is applied across these, the thickness of the film reduces due to electrodes Coulomb attraction and, in the meantime, it expands in area. This compression/extension mechanism can be used as an electric-induced mechanical actuator. In order to obtain right compression, *high DC voltage* and hence *high electric field* must be involved. Limitations to this mechanism have to be found in electromechanical breakdown.

**Problem definition:** The right *operating voltage* of an EAP at its *peak performance* is, unfortunately, very close to the breakdown voltage: at the best device’s efficiency, it is also very likely to suddenly break down. It has been shown that by pre-stretching the material, the breakdown voltage can be pushed further, but the actual physical reason of why this happens is still unclear. One possible answer relies on the less defects density (at constant electrode surface) that shows as a result of stretching.
Methodology: The main goal of this research is to analyse how the breakdown voltage varies by varying keeping the electrode surface constant and varying the pre-stretch amount for different elastomeric membranes based on silicon polymers. These activities will mainly be performed in the High-voltage lab.

Research Objectives:

- Understand the mechanism of electromechanical breakdown for soft material
- Design an effective setup for suitable and repetitive tests
- Fill a characterization table of different materials

Collaboration with Industry: NA, internal research

Contact details:
- Advisor: A. (Alessandro) Iannarelli, a.iannarelli@tudelft.nl
- Supervisor: Prof. Dr. Eng. Pavol Bauer, p.bauer@tudelft.nl
INCREASING DIELECTRIC-STRENGTH OF ELASTOMERS USED IN ARTIFICIAL MUSCLE BY MEAN OF PRE-STRETCHING.

Type of project: MSc Thesis

Scope: The scope of this project is to study how the reliability of a general electroactive polymer, used for Artificial Muscle applications, varies by improving its breakdown strength. Pre-stretching the polymer prior to its final application has been shown to be one effective way to improve dielectric failure due to electromechanical breakdown.

Background: Dielectric Electroactive Polymers (DEAP or simply EAP) have recently drawn considerable attention, because of their potential use in wave energy converters (DEG), muscle-like actuators (Artificial Muscles) and as a material for application in robotics and biomimetic. When a film of this soft polymer is coated both sides with compliant electrodes and a differential voltage is applied across these, the thickness of the film reduces due to electrodes Coulomb attraction and, in the meantime, it expands in area. This compression/extension mechanism can be used as an electric-induced mechanical actuator (The mechanism is reversible; hence inducing a deformation is possible to extract energy from the system). In order to obtain right compression, high DC voltage and hence high electric field must be involved. Limitations to this mechanism have to be found in electromechanical breakdown.

Problem definition: The right operating voltage of an EAP at its peak performance is, unfortunately, very close to the breakdown voltage at the best device’s efficiency, it is also very likely to suddenly break down. In order to increase the reliability of a final device, it is essential to push the breakdown limit further than the operational voltage. Initial pre-stretching of the film plays a fundamental role in the actuator design by significantly affecting the film properties.
Methodology: The main goal of this research is to analyse how the breakdown voltage varies by varying the pre-stretching of different elastomeric membranes based on silicon polymers, with and without fillers. These activities will mainly be performed in the High-voltage lab.

Research Objectives:

- Understand the mechanism of electromechanical breakdown for soft material
- Design an effective setup for suitable and repetitive tests
- Fill a characterization table of different materials

Collaboration with Industry: NA, internal research

Contact details:

- Advisor: A. (Alessandro) Iannarelli, a.iannarelli@tudelft.nl
- Supervisor: Prof. Dr. Eng. Pavol Bauer, p.bauer@tudelft.nl
SPACE CHARGE DEVELOPMENT IN HIGH-GRADE SILICONE BASED COMPOUND FLUID AND SOLID DIELECTRIC INTERFACES

Type of project: MSc thesis

Scope: The scope of this research project is to 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: Lovink Enertech.

Contact details:
- PhD Advisor: Guillermo Mier, G.A.MierEscurra@tudelft.nl
- Supervisor: Dr. Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
INTERFACIAL PHENOMENA BETWEEN INSULATING MATERIALS WITH ARTIFICIAL DEFECTS UNDER NON-SINUSOIDAL VOLTAGES

Type of project: MSc thesis

Scope: The scope of this project is to investigate the electrical properties and performance of insulating materials with interface in between under non-sinusoidal voltages, when typical defects are placed at the interface. The goal is to find out whether the non-sinusoidal voltages will affect the interfacial phenomena.

Problem definition: In order to improve long-term reliability of XLPE power cable systems, it is essential to guarantee a healthy condition within cable joints since they are the vulnerable areas. One factor leading to the vulnerability is the existing of the interface between cable insulation (e.g. XLPE) and joint insulation (e.g. silicone rubber), where is easy to get different defects. The insulation performance may decrease quickly under HV application particularly at the interface where there are defects. To deal with this problem, it is important to understand the degradation process and interfacial phenomena in insulations with defects, which can be achieved by investigating the electrical properties and performance of the insulations under HV, such as conductivity, permittivity, dielectric loss angle and partial discharge level. Although a certain studies have been done under AC voltage, the interfacial phenomena with defects under non-sinusoidal voltages have not been fully understood yet.

Methodology: Good understanding of interfacial phenomena in dielectric materials have to be achieved firstly. The typical types of defects that might appear at insulation interface in cable joints have to be identified by means of literature review. Then the samples that can represent the interfacial phenomena with artificial defects have to be produced in the HV lab. Non-sinusoidal waveforms have to be generated to HV level. Then the samples are subjected to the generated non-sinusoidal waveforms and their electrical properties and performance have to be measured.

Research Objectives:
To identify the typical types of defects present mostly at solid insulation interface like cable joint.

To produce samples containing interface with identified representative defects.

To select or define the non-sinusoidal voltages and generate them in the HV lab.

To do HV measurements on samples under the generated non-sinusoidal voltages.

To analyse the measurement results in order to investigate the influence of non-sinusoidal voltages on interfacial phenomena with artificial defects.

Collaboration with Industry: No

Contact details:

- PhD Advisor: Jiayang Wu, J.wu-3@tudelft.nl
- Supervisor: Dr. 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:

- Supervisor: Dr. Luis Castro Heredia, l.c.castroheredia@tudelft.nl
  Dr. Armando Rodrigo Mor, a.rodrigomor@tudelft.nl
INFLUENCE OF HTS CABLE ON TRANSIENT BEHAVIOUR OF POWER SYSTEM

Type of project: MSc thesis

Scope: The scope of this project is to study the transient behaviour of 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: NA

Contact details:
- Supervisor: Dr. Babak Gholizad, b.gholizad@tudelft.nl
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  Dr. Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
  Dr. Mohamad Ghaffarian Niasar, M.GhaffarianNiasar@tudelft.nl
AC LOSS MODELLING IN SUPERCONDUCTING TAPES AND CABLE

Type of project: MSc 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 $\mathbf{E}$ 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 $\mathbf{E}.\mathbf{J}$. 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

Contact details:
- Supervisor: Dr. Babak Gholizad, b.gholizad@tudelft.nl
  Dr. Rob Ross, R.Ross-Bikker@tudelft.nl
  Dr. Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
  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 glass insulators. The model should 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 can 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 sevirei 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 (Internal research)> 

TUD research staff members: Dr. Armando Rodrigo Mor, Ir. Peter Vaessen , Dr. Rob Ross, Ing. Paul van Nes, Ir. Radek Heller.

Contact details:
- PhD Advisor: Ir. Mahyar Gholizadeh, M.Gholizadeh@tudelft.nl
- Supervisor: Dr. Mohamad Ghaffarian Niasar, M.ghaffarianNiasar@tudelft.nl
**DESIGN AND CONSTRUCTION OF AN ACOUSTIC PD DETECTION SYSTEM**

**Type of project:** MSc thesis

**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:**
- To design and construct an acoustic PD detection system suitable for measurement of external discharges

**Collaboration with Industry:** No

**TUD research staff members:** Dr. Armando Rodrigo Mor, Ir. Peter Vaessen, Dr. Rob Ross, Ing. Paul van Nes, Ir. Radek Heller.

**Contact details:**
- Supervisor: Dr. Mohamad Ghaffarian Niasar, M.GhaffarianNiasar@tudelft.nl
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>

TUD research staff members: Dr. Armando Rodrigo Mor, Ir. Peter Vaessen, Dr. Rob Ross, Ing. Paul van Nes, Ir. Radek Heller

Contact details:
- Supervisor: Dr. Mohamad Ghaffarian Niasar, M.GhaffarianNiasar@tudelft.nl
DC AND LI TESTING

Type of project: MSc Thesis

Scope: Two possible topics have been proposed by high-voltage laboratory of SMIT to be researched at TU Delft. The main goal is to develop the knowledge rules for measurement of the DC resistance of the insulation and lightning impulse testing of the transformer. The two topics can be combined into one and their details are presented below.

Problem Definition:

1) Impulse testing time optimization

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 manufactured by SMIT are tested with positive polarity as well as requested by the customers. Currently, after the negative polarity testing sequence is completed, a period of 1 hour is used as waiting time before the positive impulses applied. The reason behind this specific waiting duration is also not known.

The goal of SMIT is to reduce the waiting time so that the efficiency of testing 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.

2) The measurements of insulation DC resistance and results interpretation

The DC resistance measurements of the 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 behaviour 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). Currently at SMIT, the resistance is measured after 15 seconds and later on after 1 minute from the moment the voltage is applied.

SMIT is searching for 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:
Royal SMIT

Contact details:
- Supervisor: Dr. Armando Rodrigo Mor, A.RodrigoMor@tudelft.nl
**RADIAL SPACER WINDING**

**Type of project:** MSc Thesis

**Scope:** The latest research performed at TU Delft related to the standing time shortening has been finished. This document contains description of a project that is to be proposed to the high-voltage group as a research topic.

**Problem Definition:**

Optimization of the dielectric design rules for the radial spacer winding.

The radial spacer winding type is relatively new for SMIT. The dielectric design rules still 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. 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.

The goal of the research is to determine the limits of the dielectric strength of the radial spacer winding. This is to be done by dielectric withstand tests of a real winding model. 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 make the test object in the shape of two coils of wire separate by spacers arranged in radial direction. An example of such arrangement can be seen on the right part of the figure above.
What SMIT is searching is 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.

The research can be split into a couple of parts:

- elaboration and development of the test set up – to be discussed between TU Delft and SMIT
- investigation of the breakdown voltage for different sizes of the insulation by performing a number of tests
- evaluating the breakdown mechanism
- the statistical analysis of the obtained results
- the comparison of the results to the outcomes of A. Singurian (2012 – Delft) and pointing the reasons for possible differences
- in parallel to the above, a literature study on similar topics (e.g. papers by M. Ikeda from Toshiba Co.), comparison of the results and discussion pointing obtained differences and similarities.

Collaboration with Industry:
Royal SMIT

Contact details:
- Supervisor: Dr. Armando Rodrigo Mor, A.RodrigoMor@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:
A thorough analysis based on numerical simulations should be done to predict all possible causes of common mode voltage. Then for each cause, hardware or control approaches to reduce the influence of it should be proposed. The proposed approaches can be validated first by simulation then through experiments on a six-phase modular permanent magnet machine.

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:
NA (Internal Research)

Contact details:
- PhD Advisor: Udai Shipurkar (U.Shipurkar@tudelft.nl)
- Supervisor: Dr. Henk Polinder (H.Polinder@tudelft.nl)
  Dr. 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 by investigating the temporal and spatial harmonics in the air gap magnetic field 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:
A dynamic circuit model which can obtain the current waveforms considering the spatial harmonics has to be built first. Then the calculated current waveforms are used with a pre-developed analytical model to obtain the air-gap flux density harmonics and radial forces. The radial force result then is used with a pre-developed noise model to predict the noise. For measurement, the system can be built based on a professional sound card with software developed in MATLAB.

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:
NA (Internal Research)

Contact details:
- Supervisor: Dr. Henk Polinder (H.Polinder@tudelft.nl)
  Dr. Jianning Dong (J.Dong-4@tudelft.nl, LB03.630)
NOISE ANALYSIS FOR LARGE TORQUE LOW SPEED MODULAR PERMANENT MAGNET MACHINE

Type of Project: Master's 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 and numerical simulation are needed to predict the modal behaviour of the stator. Radial electromagnetic force should be predicted analytically or through offline calculated FEM results. Coupled numerical simulation or analytical tool has to be built to predict the noise.

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:
NA (Internal Research)

Contact details:
- Supervisor: Dr. Henk Polinder (H.Polinder@tudelft.nl)
  Dr. Jianning Dong (J.Dong-4@tudelft.nl, LB03.630)
PEDALLED HUMAN POWER AT HOME

Type of Project: Extra project/SIP2

Epidemic increase of obesity in the western world, including The Netherlands, is a major cause of heart and vascular diseases and diabetes, causing major concerns in population health as well as increased health care costs. Scientific studies have shown that half an hour exercise a day can significantly improve health and reduce the risk of above mentioned conditions. Furthermore, the energy generated by pedalling can be saved in battery and used as part of the household consumption. The amount of produced energy is not huge, but multiplied by a large number of people can make a difference in energy consumption and CO₂ reduction, while serving the main purpose of contributing to a healthy lifestyle.

Scope:
To finalise the hardware implementation of the human power generation system consisting of a bike, generator, power electronics and battery.

Problem definition:
The task of the project is to complete the hardware implementation of the bike generator system. The system components are present and basic functionality is working as a result of the previous extra project but there are still issues to be completed. The system is meant to be demonstrated at a medical conference, so the system should be sufficiently robust and easy to use for a non-technical person.

Collaboration with Industry: Yes, UMC hospital Nijmegen.

Contact details:
- PhD Advisor: Pavel Purgat, ppurgat@tudelft.nl
- Supervisor: Dr. Jelena Popovic, j.popovic@tudelft.nl
3D TRANSIENT MODELLING OF A BRUSHLESS DOUBLY-FED INDUCTION MACHINE USING ITERATIVE SOLVERS

Type of Project: Master's Thesis

Scope: To develop a 3D transient model of a Brushless Doubly-fed Induction Machine, involving rotor motion and calculation of the rotor current. Incorporating end-winding effects, anisotropic materials and skewed conductors.

Background: Speed control of generator in wind turbines is essential to maximize the power output from the system. Brushless Doubly-fed Induction Machines (BDFIMs) offer this possibility without the need for slip-ring and brush-gear arrangement. This makes them more reliable and less prone to frequent maintenance; which otherwise can be a very costly exercise, especially for offshore wind farms.

Problem definition: Efficient 3D transient modelling of the BDFIM, involving rotor motion and rotor circuit equations, using iterative solvers and preconditioners.

Methodology: 2D models build for the BDFIM neglect end-winding effects, anisotropy of the iron, etc. 3D models can be used to address these limitations. However, full-scale 3D transient models solved using the same methods as 2D are extremely expensive both in terms of computational memory and time. Therefore, possibly new methods need to be investigated to enable 3D transient modelling of electrical machines, in general, and the BDFIM, in particular.

In this thesis, the student is expected to improve upon the 3D Magnetostatic model developed recently in the department. The project would involve extensive modelling in 3D finite elements using COMSOL Multiphysics software (or any other software as chosen by the student). Previous knowledge about finite element modelling and linear algebra is desirable.

Research Objectives:
- Develop a 3D transient model of the BDFIM using finite element methods.
- The 3D model should have the ability to calculate the rotor currents implicitly.
- Resulting system of equations is to be solved using iterative methods and preconditioners.

Collaboration with Industry: No

Contact details:
- PhD Advisor: Faisal Wani, f.m.wani@tudelft.nl
EFFECT OF ROTOR END-WINDING INDUCTANCES IN A BRUSHLESS DOUBLY-FED INDUCTION MACHINE

Type of Project: Master’s Thesis

Scope: To calculate the end-winding inductance in the BDFIM rotor and analyse its impact on the magnitude of the rotor currents obtained using the 2D transient model.

Background: Speed control of generator in wind turbines is essential to maximize the power output from the system. Brushless Doubly-fed Induction Machines (BDFIMs) offer this possibility without the need for slip-ring and brush-gear arrangement. This makes them more reliable and less prone to frequent maintenance; which otherwise can be a very costly exercise, especially for offshore wind farms.

Problem definition: Calculation of the end-winding inductance of the BDFIM rotor using 3D finite element modelling, and coupling the derived values in the 2D transient models to assess its impact on the magnitude of rotor currents and other performance parameters.

Methodology: 2D models build for the BDFIM neglect end-winding effects, anisotropy of the iron, etc. 3D models can be used to address these limitations. However, full-scale 3D transient models are complex as well as expensive both in terms of computational memory and time. Therefore, a balance has to be struck between accuracy and efficiency of the model.

In this thesis, the student is expected to build and improve upon the models (both 2D and 3D) previously developed in the department. The project would involve extensive modelling in 2D as well as 3D finite elements. Previous knowledge about finite element modelling and linear algebra is desirable but not mandatory. The project would mostly involve simulations in COMSOL Multiphysics (or some other FEM software if so desired). There is also a possibility for some laboratory work.

Research Objectives:
- Using 3D FEM, estimate the end-winding inductances for the nested-cage rotor.
- Incorporate end-winding inductance in 2D transient models.
- Analyse its effect on performance parameters such as torque, ripple, etc.

Collaboration with Industry: No

Contact details:
COORDINATED CONTROL FOR LVRT ENHANCEMENT IN WIND TURBINES WITH BDFIG

Type of Project: Master’s Thesis

Scope: This project will focus on improving Low Voltage Ride Through capability of Brushless doubly fed induction generator by introducing and implementing coordinated control scheme.

Problem definition: The grid side inverter (GSI) is controlled to limit the dc-link overvoltage during the voltage drop. Since the dc-link dynamics is nonlinear, the linear control scheme cannot properly limit the dc-link voltage under large voltage dips. Thus, a nonlinear control scheme applied to the GSI can be proposed, which stabilizes the stator dynamics and limits the dc-link voltage fluctuations during the fault. Since, during asymmetrical faults, the rotor voltage has a large and permanent negative-sequence component and the rotor voltages are higher and more damaging than those for symmetrical grid dips, this method could be applicable for symmetrical and asymmetrical fault ride through.

Methodology:
- Implementing coordinated control schemes for improving LVRT of BDFIG
- The studies should be done in Matlab/Simulink. Also there is experimental set-up for verification of simulation studies.

Research Objectives:
- The proposed scheme can limit the peak values of CW current and dc-link voltage at the instants of occurring and clearing the fault.
- The proposed scheme can also limit the oscillations of electromagnetic torque, and consequently, improve the DFIG symmetrical and asymmetrical voltage dips behaviour.
- Comparing theoretical study with realistic behaviour of machine by experimental verification.

Collaboration with Industry: No

Contact details:
- PhD Advisor: Mahyar Gholizadeh, M.gholizadeh@tudelft.nl
- Supervisor: Dr. ir. Henk Polinder, h.polinder@tudelft.nl
EXPERIMENTAL PARAMETER EXTRACTION OF BRUSHLESS DOUBLY FED INDUCTION MACHINE

Type of Project: Master’s Thesis

Scope: This project will focus on parameter extraction of brushless doubly fed induction generator considering practical phenomena such as core saturation, skin effects, etc.

Problem definition: It is expected that Brushless Doubly fed induction generator, with cheaper and easier operation and maintenance option can be a deserving substitute for DFIG. So investigation of some operational modes and extracting equivalent circuit parameters of machine is necessary for resuming research on new BDFIG prototype. Since, the presented works did not consider the important operational limitations of machine such as core saturation, the result of this project would be a novel contribution.

Methodology:
- Literature review of BDFIG parameters extraction methods.
- The parameter extraction is combination of modelling and experimental study of machine behaviour during various operational mode.
- The experimental measurements should be done on existing BDFIG prototype and the results could be validated with FEM modelling.

Research Objectives:
- Investigation of different operation modes of BDFIG.
- Extracting precise equivalent circuit of machines with consideration of practical limitation.
- Compare the experimental studies with simulation results.

Collaboration with Industry: No

Contact details:
- PhD Advisor: Mahyar Gholizadeh, M.gholizadeh@tudelft.nl
- Supervisor: Dr. ir. Henk Polinder, h.polinder@tudelft.nl
GLOBAL ENERGY REQUIREMENT (GER) COMPARISON OF MODULAR AND CONVENTIONAL POWER ELECTRONIC CONVERTER

Type of Project: SIP 2/Extra Project

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

Background: Power electronic converters are the cornerstone of smart home and smart grids. Due to a large variety of power electronic solutions required in these applications, modular architectures are being re-investigated. However, only such a solution is truly sustainable that saves more energy than it consumes 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 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 Advisor: P. Purgat, p.purgat@tudelft.nl
- Supervisor: Dr. J. Popović-Gerber, j.popovic@tudelft.nl
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

Contact details:
- PhD Advisor: U. Shipurkar, U.Shipurkar@tudelft.nl
- Supervisor: Dr. Henk Polinder, H.Polinder@tudelft.nl
  Dr. 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 Advisor: Udal Shipurkar, U.Shipurkar@tudelft.nl
- Supervisor: Dr. Henk Polinder, H.Polinder@tudelft.nl
  Dr. Jianning Dong, J.Dong-4@tudelft.nl
HOT SWAP SOLUTIONS FOR WIND TURBINES

Type of Project: MSc thesis

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.

Contact details:
- PhD Advisor: Udai Shipurkar, U.Shipurkar@tudelft.nl
  Pavel Purgat, P.Purgat@tudelft.nl
  Minos Kontos, E.Kontos@tudelft.nl
- Supervisor: Dr. Henk Polinder, H.Polinder@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.

Contact details:
- PhD Advisor: Udai Shipurkar, U.Shipurkar@tudelft.nl
- Supervisor: Dr. Henk Polinder, H.Polinder@tudelft.nl
  Dr. Jianning Dong, J.Dong-4@tudelft.nl
DESIGN A DC/DC CONVERTER FOR EV CHARGING USING GAN DEVICES

Type of project: MSc thesis / Extra Project

Scope:
This Master Thesis assignment entails the design of a 5kW isolated DC/DC converter for electric vehicle charging applications (marked in green). This part of the power module is relatively unique to this application and has no equivalence in for example solar applications because of the needed isolation. It therefore warrants a separate investigation.

Problem definition:
- In the future GaN is needed to stay competitive. The prices of the devices are expected to be on par with current conventional technologies while SiC will always be a bit more expensive
- The emphasis is on technology prototype development, understanding the weak points of the technology. The sooner we can take new technologies for a spin “outside of the lab”, the better.
- The prototype will not immediately be ready for large scale production, but it is close enough for a small runs.

Methodology:
A possible timeline for the project can be:
- Set general requirements (420Vin +/- 20Vripple due to PFC, 200-1000Vout, 15A, .15A ripple, 5kW, Capacitive-load)
- 2 months literature study -> 1 chapter
- 2 months simulating 3-5 topologies -> 1 chapter
- Refine requirements
- Select 1-2 topologies for possible implementation
- 2 months detailed design of these 1-2 topologies -> 1 chapter
- 2 months implement, test and benchmark -> 1 chapter
- 1 month write report

Research Objectives:
- Compare different topologies and implement a technology prototype, utilizing GaN (and SiC diodes)
• This prototype should be benchmarked against 2 implementations, one using IGBTs and one using GaN
• This new design should give a benefit for:
  o Cost
  o Efficiency
  o Power density

Collaboration with Industry:
Yes, ABB is one of the biggest DC fast charger manufacturers in the world

Contact details:
• PhD Advisor: Gautham Ram, G.R.ChandraMouli@tudelft.nl
• TUDelft Supervisor: Pavol Bauer, P.Bauer@tudelft.nl
• Company Supervisor: Stefan Raaijmakers, stefan.raaijmakers@nl.abb.com
DEVELOPMENT AND TEST OF A SMART GRID FUNCTIONS AND PROTOTYPE FOR AN INTEGRATED PHOTOVOLTAIC / BATTERY STORAGE SYSTEM

Type of project: MSc thesis

Scope: Solartechno Europe B.V. is a specialist in PV solar technology and energy storage. We are developing a new family of products that combines lithium-ion batteries with solar panels. Those products are being developed at the European Space Agency Business Incubation Centre in Noordwijk.

Your internship will be in a very international setting and will also give you a view on what it takes to take a prototype into commercialization.

Problem definition: We have developed a family of integrated, modular, plug and play battery with on board battery charger and battery Management System. The latest product of this family must also have on board integrated smart grid functions, such as “charge the battery if the grid price of electricity is low and there is no sun tomorrow”, “switch on the dryer because the battery is full and tomorrow there is sun”, “sell electricity to the grid operator”. The student will start by writing the user cases, then write the specifications, define a concept design, look what is already available on the market. Also the additional requirements on the existing hard- and software shall be investigated in order to enable the identified smart grid functionality, and initial prototypes shall be prepared for testing.

Collaboration with Industry: Yes, Solartechno Europe BV, Cedel BV

Contact details:

- Industry supervisor: Ir. Marco Ghirardello marco@solartechno.com
  Tel 0203340120
- TUDelft Supervisor: Pavol Bauer, P.Bauer@tudelft.nl
DEVELOPMENT AND TEST OF A COMMUNICATION SYSTEM FOR AN INTEGRATED SOLAR PANEL – BATTERY STORAGE MODULE

Type of project: Internship

Scope: Solartechno Europe B.V. is a specialist in PV solar technology and energy storage. We are developing a new product that combines lithium-ion batteries with solar panels. This new product is being developed at the European Space Agency Business Incubation Centre in Noordwijk.

Your internship will be in a very international setting and will also give you a view on what it takes to take a prototype into commercialization.

Problem definition: We have developed an integrated battery unit with on board battery charger, Battery Management System. You will evaluate the current prototype design and develop a communication system to read out the main battery parameters (voltage, current, state of charge, temperatures, solar panel production, errors and alarms more information). The data should be saved on a server in the cloud and the manufacturer / customers should be able to read it. Visualization of data should be with an app on a smart phone. The new design should be the final one for large scale industrialization.

Collaboration with Industry: Yes, Solartechno Europe BV, Cedel BV

Contact details:

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  Tel 0203340120
- TUDelft Supervisor: Pavol Bauer, P.Bauer@tudelft.nl
DEVELOPMENT AND TEST OF A MICRO INVERTER FOR AN INTEGRATED SOLAR AND BATTERY STORAGE SYSTEM

Type of project: Internship

Scope: Solartechno Europe B.V. is a specialist in PV solar technology and energy storage. We are developing a new product that combines lithium-ion batteries with solar panels. This new product is being developed at the European Space Agency Business Incubation Centre in Noordwijk.

Your internship will be in a very international setting and will also give you a view on what it takes to take a prototype into commercialization.

Problem definition: Currently we are focusing on the Communication Market, where 48 Vdc power is the standard supply. For other markets and applications there is more need for 230/115 Vac power supplies, for which a (micro) DC – AC converter is required. This converter can be developed but the question in that case will be: what is the added value compared with the competition, or it can be bought. In both cases the converter must be optimized in power efficiency, must be integrated with the existing 48Vdc hardware. Another important design aspect is that the integrated module has to operate under relatively high environmental temperature conditions in a closed environment without an active cooling system.

Collaboration with Industry: Yes, Solartechno Europe BV

Contact details:
- Industry supervisor: Ir. Marco Ghirardello marco@solartechno.com
  Tel 0203340120
- TUDelft Supervisor: Pavol Bauer, P_Bauer@tudelft.nl
DESIGN OF NEW BATTERY PACKS STARTING FROM THE RECYCLING OF DIFFERENT TYPES OF ELECTRIC CAR BATTERY PACKS AND BATTERY CELLS

Type of project: Internship

Scope: Solartehno Europe B.V. is a specialist in PV solar technology and energy storage. We are developing a new product that combines lithium-ion batteries with solar panels. This new product is being developed at the European Space Agency Business Incubation Centre in Noordwijk.

We are starting to recycle electrical cars batteries into battery packs for off grid systems.

Problem definition: Currently we have available several different types of lithium batteries packs from more car manufacturers. Batteries and cells have different chemistries and voltages. We also are installing large off grid system with energy storage systems (48 Vdc power is the standard supply). We would like to have a technical economic feasibility study to define the best way to recycle the available batteries. We would like to design, build and test some “standard and modular” battery packs. Safety is our main concern, followed by technical and economic feasibility. The student should be able to design and / or integrate in a single product new and on the shelf components.

Collaboration with Industry: Yes, Solartehno Europe BV

Contact details:

- Industry supervisor: Ir. Marco Ghirardello marco@solartehno.com
  Tel 0203340120
- TUDelft Supervisor: Pavol Bauer, P.Bauer@tudelft.nl
OPTIMUM PHASE SHIFT IN INTERLEAVED PFC CIRCUITS

**Type of project:** MSc thesis

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.

**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 v(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:** Nil

**Contact details:**
- PhD Advisor: Wenbo Wang, wenbo.wang@tudelft.nl
- Supervisor: Frans Pansier, F.Pansier@tudelft.nl
OPTIMAL PV FEED-IN TARIFFS FOR PROSUMERS AND DSO

Type of project: MSc thesis

Research Objectives: To determine the optimal PV feed-in tariffs considering both prosumers and DSO (distribution system operators)

Problem definition: Several different feed-in tariff (FIT) mechanisms are being currently proposed by different DSOs around the world. Prosumers want a high FIT which will lower their PV systems' payback period. On the other hand, DSOs want to provide low FIT that will match wholesale electricity prices. What is the optimal FIT that would sustainably benefit both the prosumers and DSOs, paving the way for a more sustainable national energy mixes?

Methodology:
1. Understand the underlying principles of energy makers and pricing of electricity and FIT
2. Analyse the different PV FIT proposed by utilities around the world. Quantify the energy/economic benefits they provide to the prosumer and the DSO
3. Assess the impact of seasonal variations in PV production for FIT. Compare the cases of Costa Rica, India, Netherlands, and Germany
4. Investigate the influence of storage to grid-integrated PV systems from the point of view of FIT and market models
5. Propose an optimal FIT mechanism that provides optimal returns for both the prosumer and the DSO under different scenarios (different geographies, and different levels of PV grid penetration)

Necessary background: PV systems, energy markets

Collaboration with Industry: Nil

Contact details:
- PhD Advisors: Gautham Ram, G.R.ChandraMouli@tudelft.nl
  Victor Vega, V.E.VegaGarita@tudelft.nl
  Nishant Narayan, N.S.Narayan@tudelft.nl
- Supervisor: Pavol Bauer, P.Bauer@tudelft.nl
SMART CHARGING OF EVS USING AN ENERGY MANAGEMENT SYSTEM

Type of project: MSc thesis

Research Objectives: Practical implementation of smart EV charging by using an energy management system (EMS)

Problem definition: Jedlix is a smart charging company that lets EV owners to smart charge their cars and pays EV owners for it. Currently, they use simple algorithms for charging the EV and would like to expand them. In the EEMCS faculty, algorithms have been developed that use dynamic grid prices, EV user preferences, distribution network constraints and solar forecast to control the charging of a fleet of EV. In the next step, Jedlix and TU delft want to collaborate together to develop the algorithms together and test them in the real world with a fleet of EV

Methodology:
1. Analyse
   a. Energy management system (EMS) built at TU Delft based on (Microsoft solver foundation, C# and SQL server) and (GAMS, Matlab)
   b. The control of EV charging as implemented by Jedlix in their chargers
2. Develop the objective function, input parameters and constraints for the smart charging algorithm in collaboration with Jedlix
3. Implement the algorithm in the form of software that can be run on the Jedlix system.
4. Run it in parallel on the same input data as Jedlix' own system, while not controlling the charging, but showing the potential increase in profit
5. Implement practical tests to control real EV charging based on commands from the EMS

Necessary background: Optimization, C, C# coding, knowledge of database/SQL, hardware testing

Collaboration with Industry: Yes (Jedlix)

Contact details:
- PhD Advisor: Gautham Ram, G.R.ChandraMouli@tudelft.nl
  Mathijs de Weert, Algorithmics Group, m.m.deweerdt@tudelft.nl
- Supervisor: Pavol Bauer, P.Bauer@tudelft.nl
FREQUENCY CONTROL FOR (DIS)CONNECTION OF TWO CSGriP CELLS AT SEND LAB

Type of project: MSc thesis

Scope: The SOPRA system combines an energy storage system with renewable energy sources and a backup diesel generator in order to meet the local demand. The CSGriP project focuses at coupling different SOPRA systems to enhance the system redundancy and power delivery capability. The interconnection and disconnection are pursued by implementing frequency control to prevent the need of ICT.

Problem definition: When two CSGriP cells are (dis)connected, they may experience large frequency and voltage deviations. To avoid this problem, advanced control methods are required to ensure seamless transition during (dis)connected.

Methodology: The (dis)connection of two cells will be investigated at the Smart ENergy Delivery Lab (SEND lab) which is under development at AVANS University of applied Science. http://www.avans.nl/onderzoek/expertisecentra/duurzame-innovatie/lectoraten/smart-energy/ This lab enables innovative, applied research in the field of micro grids by flexible (dis)connection of multiple renewable sources, demand and storage systems in an interactive way at safe voltage levels. The SEND lab possesses a Back-to-Back inverter research board and a General Propose Inverter Controller GPIC (National Instrument) as control platform. Labview is used as programming language.

Research Objectives:
- Design and implementation of a bi-directional DC-DC converter and inverter.
  - Hardware platform: Back-to-Back inverter research Board
  - Control platform: General Propose Inverter Controller GPIC (National Instrument)
  - Software Platform: Labview
- Implementation of frequency control protocols for charging and discharging of the battery systems
- Specification and development of system as part of the SEND lab
- Testing of set up during (dis)connection of two cells
- Validation of test results

Collaboration with Industry: DNV GL, AVANS University.

Contact details:
- Advisor: Dr. Seyedmahdi, S.Izadkhast@tudelft.nl, LB 03.830
- Supervisor: Pavol Bauer, P.Bauer@tudelft.nl
ADVANCED CONTROL STRATEGIES FOR MULTI-SERVICE BATTERY ENERGY STORAGE SYSTEMS WITHIN DISTRIBUTION NETWORKS

Type of project: Master Thesis

Research Objective: To formulate and develop advanced control strategies for multi-service battery energy storage systems in distribution networks.

Problem definition: In order to make battery energy storage systems (e.g., Tesla Powerpack and Tesla Powerwall) more cost-effective, they are to simultaneously provide a wide variety of electricity ancillary services (e.g., voltage control and energy arbitrage) within electrical distribution networks. To achieve this end, multi-service battery energy storage systems are to be properly operated and well managed. However, this is a complex and challenging task, since there is a clear trade-off between the battery life and the performance of multi-service battery energy storage systems. Therefore, advanced control strategies for battery energy storage systems are required to be proposed and developed to simultaneously provide a number of electricity services, while preserving the battery life.

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

Necessary background: Power systems, control.

Contact details:
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- Supervisor: Prof. dr. eng. Pavol Bauer, P.Bauer@tudelft.nl
### DESIGN OF SWITCHED BOOST INVERTER (SBI) FOR DC NANOGRID APPLICATIONS

**Type of project:** MSc thesis

**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 overall system, thus holding a huge potential for applications in future dc Nanogrids.

**Problem definition:** Future dc nanogrids like households, data centers 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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**Contact details:**

- PhD Advisor: S. Bandyopadhyay, s.bandyopadhyay-1@tudelft.nl
- Supervisors: Dr. Ir. Laura Ramirez-Elizondo, L.M.RamirezElizondo@tudelft.nl
  Prof. dr. eng. Pavol Bauer: P.Bauer@tudelft.nl
THERMAL MODELLING TO DETERMINE POWER DENSITY LIMITS OF WIRELESS INDUCTIVE COUPLERS FOR EV CHARGING

Type of project: MSc thesis

Scope: The possible flexibilities and potential of wireless charging makes it a prime candidate of replacing conventional wired charging of EVs. However, as the power increases the loss density and thermal behaviour become the limiting factor. That’s why quantifying the power density limits of the inductive couplers is very important for designers.

Problem definition: Wireless inductive power charge-pads use materials like litze wire, ferrites and aluminium which are relatively more expensive than normal copper wires and insulations needed for wired charging. Charge-pads are of different shapes like DD coils, circular coils, rectangular coils and their loss distribution can be different depending on core layouts. The goal of this thesis will be to find the thermal weak-links and thus the power density limits of the charge-pads with or without cooling.

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

- Literature review of inductive charge-pad cooling and thermal modelling
- Thermal modelling using 3D FEM modelling and as well as lumped parameter modelling
- Optimisation of coil shapes and experimental validation of models

Research Objectives: The pertinent research objectives are highlighted below:

- Design guidelines for thermal management of high power IPT systems
- Design trade-offs w.r.t power density and thermal considerations
- Comparison of coil shapes based on thermal limits

Collaboration with Industry: No

Contact details:
- PhD Advisor: S. Bandyopadhyay  s.bandyopadhyay-1@tudelft.nl
- Supervisors: Prof. dr. eng. Pavol Bauer: P.Bauer@tudelft.nl
DESIGN OF WIRELESS CHARGING SYSTEM AND CONTROL FOR SMART CHARGING OF EVS

Type of project: MSc thesis

Scope: The possible flexibilities and potential of wireless charging makes it a prime candidate of replacing conventional wired charging of EVs. The current research are mainly based on designing wireless systems for maximum power transfer (6-11 kW). However, in future grids it might be useful to have variable power charging to match stochastic nature of renewable based generation and use of storage energy. Therefore, design and control of wireless power systems for smart charging of EVs is an interesting research area.

Figure 1: Wireless EV charging and Bi-directional power electronics topology

Problem definition: Future dc nanogrids like households will be equipped with solar power and battery based energy storage. They are also expected to deliver power to charge EVs (Level-1/Level-2 charging). Therefore, an optimal topology has to be investigate which can deliver variable power bi-directionally with reasonable partial load efficiencies.

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

- Literature review of variable power inductive power topologies
- Selection of optimal inverter and dc-dc converter topologies and control strategy
- System based multi-objective optimization

Research Objectives: The pertinent research objectives are highlighted below:

- Design guidelines for topology selection for variable power IPT systems
- Design trade-offs w.r.t efficiency, flexibility and cost
- Demand-response capabilities of EV storage

Collaboration with Industry: No

Contact details:

- PhD Advisor: S. Bandyopadhyay s.bandyopadhyay-1@tudelft.nl
  Gautham Ram, G.R.ChandraMouli@tudelft.nl
- Supervisors: Prof. dr. eng. Pavol Bauer: P.Bauer@tudelft.nl
BLOCKCHAIN FOR DISTRIBUTION GRIDS

Type of project: MSc thesis

Scope: In the future it is expected that the blockchain will play a big role in trading distributed sustainable energy. The goal is to identify the advantages and challenges of applying blockchain technologies to the 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. Therefore, 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 the various blockchain technologies
- Identify the advantages and challenges of blockchain technologies for DC distribution grids
- Analyse case studies

Contact details:

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- 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 a big challenge. The goal is to analyse the stability of DC Distribution grids by using impedance criteria, small signal analysis, and/or eigenvalue analysis.

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. One of these challenges is its stability. 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.

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
- Analyse case studies

Contact details:
- PhD Advisor: 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 challenge. 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, calculations 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

Contact details:

- PhD Advisor: 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
Type of project: MSc thesis

Scope: The cost of the solar systems has to be reduced in order to compete with other energy sources. In particular, the installation cost and the cost of the balance of systems components can be reduced by physically integrating of a PV-battery Integrated Module (PBIM). In this device, the batteries, charge controller, and microinverter are located on the back side of a PV panel.

Problem definition: A PBIM can be used for many applications. It is possible to perform peak shaving, supply a residential load when connecting several PBIMs, and be applied in stand-alone solutions. The challenge is to assess the effectiveness of this solution in the proposed scenarios. Moreover, the best control strategies must be defined, as well as an optimized energy management system.

Methodology:
- Review the current literature on the topic.
- Develop a model of the PBIM to be used in various scenarios.
- Compare the results obtained for the PBIM to the conventional PV-battery solutions.
- Define optimization parameters to evaluate the effectiveness to the PBIM.

Research Objectives:
- Identify, purpose, and select the most promising applications of the PBIM.
- Evaluate the performance of the PBIM in different applications.
- Find the optimum energy management strategies to control the energy flow in the PBIM.
- Propose a final design of PBIM for general applications.

Collaboration with Industry: No

Contact details:
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  Prof. Pavol Bauer, p.bauer@tudelft.nl
**DC SIMULATION MODEL LIBRARY**

**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:**

- **Advisor:** dr. Ir. Peter van Duijsen, B36-LB 03.820, [P.J.vanDuijsen@tudelft.nl](mailto:P.J.vanDuijsen@tudelft.nl)
- **Supervisor:** Prof. dr. Ir. Pavol Bauer, LB 03.600, [p.bauer@tudelft.nl](mailto:p.bauer@tudelft.nl)
DESIGN AND CONSTRUCTION OF A LAB-SCALED MMC-VSC CONVERTER

Type of project: SIP II/ MSc thesis (Starting date: December 2016)

Scope: The goal is to construct a low-voltage low-power MMC-VSC converter in the laboratory to verify with the best accuracy the real full-scale HVdc converter behaviour.

Problem definition: The construction of an MMC is a delicate task which requires good planning. First, the converter specification need to be defined and the hardware requirements need to be chosen accordingly. Then, theoretical calculations and simulations are needed to design the control structure of the converter and the communication system. Finally, the converter needs to be assembled and tested to verify its simulated operation.

Methodology: This project comprises both a simulation and a testing phase. First, simulations of the lab-scaled converter will be carried out in order to properly tune its controllers and verify its operation. Secondly, the converter will be built and tested.

Research Objectives:
- Build a fully-operational MMC converter;
- Verify the control of the converter applying different control strategies;
- Compare the MMC test results with the simulation results made in Matlab/Simulink.

Contact details:
- PhD Advisor: Epameinondas (Minos) Kontos, LB 03.690, e.kontos@tudelft.nl
- Supervisor: Dr. Ir. Pavol Bauer, LB 03.600, p.bauer@tudelft.nl
LOSS MODELLING OF DC BREAKERS FOR HVDC APPLICATIONS

Type of project: SIP II/ MSc thesis (Starting date: December 2016)

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 Matlab code.

Contact details:
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- Supervisor: Dr. Ir. Pavol Bauer, LB 03.600, p.bauer@tudelft.nl
ELECTRICAL MODELLING OF BATTERY PACKS FOR PV-STORAGE SYSTEMS

Type of project: MSc thesis

Scope: Battery storage is usually the most expensive part of the modern-day PV-storage system. Therefore, it is important to be able to accurately predict the battery behaviour to get the most out of it without compromising its lifetime. Battery modelling is a complex task because of the various electrical, chemical and thermal phenomena linked to its operation. This project focuses on the electrical behaviour and modelling of the battery storage system.

This project is part of two larger PhD projects. One of them is 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. The other PhD project is focused on the physical integration of a PV-battery system. Energy storage will be an integral part of these projects.

Problem definition: For different battery technologies (Lead Acid, Li-ion and variants, Ni-Fe), an electrical model needs to be made at two levels – cell level and eventually battery pack level. Some cell-level models already exist in literature, but battery pack level electrical models are not as common due to the dependency on cell configurations and packaging differences. Battery level model will help in determining cells that are likely to fail first in the battery lifetime, giving a more accurate operational battery lifetime number.

Methodology: After understanding cell-level electrical models from literature, the student is expected to build upon existing cell-models for different technologies (work already done in the DCES group) as a start. Based on the operational requirements of the PV system (C-rates, V, I, imposed on the battery), environmental conditions and different cell configurations, the student will need to accurately model the electrical behaviour (V, I and possibly SOC) and therefore capacity fading of the whole battery system.

Research Objectives:
- To build electrical models of different cell configurations across battery technologies.
- To determine the impact on battery life among the cells in the battery pack under different use-case and environmental conditions.
Collaboration with Industry: Possible collaboration with a battery start-up.

Contact details:

- PhD Advisors: Victor Vega, V.E.VegaGarita@tudelft.nl
  Nishant Narayan, N.S.Narayan@tudelft.nl

- Supervisor: Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
  Dr. Ir. Pavol Bauer, LB 03.600, p.bauer@tudelft.nl
THERMAL MODELLING OF BATTERY PACKS FOR PV-STORAGE SYSTEMS

Type of project: MSc thesis

Scope: Battery storage is usually the most expensive part of the modern-day PV-storage system. Therefore it is important to be able to accurately predict the battery behaviour to get the most out of it without compromising its lifetime. Battery modelling is a complex task because of the various electrical, chemical and thermal phenomena linked to its operation. This project focuses on the thermal behaviour and modelling of the battery storage system.

This project is part of two larger PhD projects. One of them is 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. The other PhD project is focused on the physical integration of a PV-battery system. Energy storage will be an integral part of these projects.

Problem definition: For different battery technologies (Lead Acid, Li-ion and variants, Ni-Fe), a thermal model needs to be made at two levels – cell level and eventually battery pack level. Some cell-level models already exist in literature, but battery pack level thermal models are not as common due to the dependency on cell configurations and packaging differences. Battery level model will help in determining cells that are likely to fail first in the battery lifetime.

Methodology: After understanding cell-level thermal models from literature, the student is expected to build the cell-models for different technologies as a start. Based on the electrical behaviour of the PV system (C-rates imposed on the battery), environmental conditions and different cell configurations, the student will need to accurately model the thermal behaviour of the whole battery system. Effect of dedicated cooling may be added to the model.

Research Objectives:
- To build thermodynamic models of different cell configurations across battery technologies.
- To determine the temperature distribution among the cells in a battery pack under different environmental conditions.

Collaboration with Industry: Possible collaboration with a battery start-up.

Contact details:
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- Supervisor: Laura Ramirez Elizondo, L.M.RamirezElizondo@tudelft.nl
  Prof. dr. Ir. Pavol Bauer, LB 03.600, p.bauer@tudelft.nl
NICHE STRATEGIES FOR MAXIMIZING SUCCESSFUL PENETRATION OF SOLAR HOME SYSTEMS (SHS) FOR RURAL ELECTRIFICATION

Type of project: Master 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 SHS 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. 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 for specific communities, gaining a grasp on sustainable energy economics, and optimization techniques.

Suitable for: This problem statement is specifically suitable for a SET student looking for a broader view on technology application in the thesis.

Research Objectives:
- To investigate the external/soft factors affect the successful penetration of SHS in the rural households of South Africa, India and Cambodia.
- To identify the right business case so that a SHS project is financially immune to unfavourable policies and independent of subsidies

Collaboration with Industry: Industrial collaboration would be largely limited to getting field inputs on existing SHS and other 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. A collaboration with TPM faculty is expected.

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MULTI-LAYER SYSTEM INTEGRATION STUDY

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

Scope: The aim of the project is to investigate the technical and financial feasibility for integrating a wide range of distributed energy assets, ranging from consumer appliances to utility scale systems, under one overarching energy management platform. The goal is to examine how the aggregation of distributed energy resources can create opportunities for system optimization, and generate the greatest value for all involved stakeholders. The project will examine different communication protocols, technical standards, and ICT solutions for interacting with, and controlling devices, aiming to determine the viability of streamlining these divergent approaches. Furthermore, the study will include an in-depth analysis of the financial costs and benefits of implementing different technological solutions, with the aim of developing new business models for smart-grid services.

Problem definition: With the advent of digitalization, propelled by concepts like the IoT, more and more devices and systems are being connected, and an increasing amount of data is becoming available. In the process, numerous industry standards and protocols for control, communications, and data storage have emerged. The use of all these different standards makes it more difficult to streamline the operations of different systems, and to enable easy integration of new hardware. Furthermore, the constraints of existing market models create challenges for commercializing smart-grid technologies, and impede the transition towards a clean energy economy.

Methodology: The project will involve conducting in-depth technical and market research, contacting suppliers, interviewing potential users, experimenting with different hardware / ICT technologies, planning tests for benchmarking, building
financial models, and producing a report to detail the process and results of the research.

Research Objectives:

- Identify the most effective and promising ICT solutions for machine-to-machine communications, data collection, real-time processing, and other specific energy management applications.
- Assess existing and emerging industry standards, and develop strategies for streamlining different approaches into one holistic system architecture.
- Determine the viability of different energy service models, enabled through energy asset aggregation, by examining several specific use-cases

Collaboration with Industry:

Spectral Utilities

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EMBEDDED SYSTEMS FOR SMART ENERGY MANAGEMENT

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

**Scope:** The position will involve working with an international consortium to realize the goals of “Grid-Friends,” an EU research project which aims to set a new standard in smart-grid technology. The project is focused on further advancement of myPowerGrid, an energy management platform which interfaces with, and controls distributed energy systems (such as batteries, power converters, and heat pumps) in order to optimize energy utilization. The scope of the internship will involve developing new control systems for managing distributed energy resources, and collecting / processing data from sensors and other devices.

**Problem definition:** In order to enable wide-scale deployment of smart-grid solutions (globally), highly reliable, yet low-cost ICT solutions are needed. Certain critical applications for energy management may demand 100% uptime, which may require developing new approaches for communication and control systems. Having precise measurements of various parameters within an energy network is essential for facilitating optimal decision making. Currently, the cost and complexity of integrating sensing equipment has proven to be prohibitive in many contexts, and therefore new, lower cost solutions are needed to allow scaling up. Creating a need for new, lower cost technology. will in Achieving this goal will require integration of flexible sensing systems for data collection and communications. will require integration of numerous sensors and data collection systems. may require developing flexible, plug-and-play
sensing modules that are inexpensive, easy to install, and have very low energy consumption.

Methodology: The internship will involve an iterative process of conducting desk research, formulating technical designs, prototyping hardware / (embedded) software, as well as applied research and testing in both simulated and real environments. The solutions which are developed will be further deployed in field trials within the smart-grid at Schoonschip, a residential community located in Amsterdam (and a member of the “Grid-Friends” project consortium).

Research Objectives:
- Design and prototype a low-cost, highly robust control system with real-time processing capabilities and built-in redundancy.
- Design and prototype a low-cost, easy to install, flexible sensing system for measurement of current, voltage, temperature, water flow, and other relevant parameters. The sensing system should be designed to have very low energy consumption.

Collaboration with Research Institutes: Centrum Wiskunde & Informatica (CWI), Fraunhofer ITWM

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AVAILABILITY AND FUNCTIONAL SAFETY LEVEL OF THE DRIVETRAIN OF A BRIDGE

Type of project: MSc thesis

Scope:
- Availability calculation of the drivetrain of a bridge.
- Functional safety level calculation of the drivetrain of a bridge.
- Optimization of availability and functional safety level.

Problem definition: The high density of traffic makes it important that bridges operate both reliably and safely. The drivetrain of the project’s bridge includes a three-phase geared AC motor, encoder, frequency inverter, brakes and a control system. What availability and what functional safety level can be achieved? How can these be improved/optimized?

Methodology:
- Analysis of relevant availability and functional safety factors in the drivetrain system for opening and closing a bridge.
- Set-up a calculation program in order to calculate the availability.
- Calculation of the Performance Level, based on EN13849, by means of the Sistema software tool.

Research Objectives:
- Develop an availability model, calculation and optimization
- Functional safety calculation and optimization.

Collaboration with Research Institutes: Yes, with SEW-EURODRIVE B.V.

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