DC Transformer Power-Reversal Development and Hardware-in-The-Loop Testing

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Project Type:	MSc Semester Project	Section:	SEL
Official Start Date:	16.02.2026		
Submission of Final Report:	June, 2026		
Presentations at Group Meeting:	Mid-term and Final Presentations (dates TBD)		
Delivery of project results:	HIL Setup, Validated control implementation, Documented investigation		

Context, Background, and Motivation:

The direct current transformer (DCT) is a key component in the realization of DC power distribution networks (PDNs), which promise to facilitate the seamless integration of inherently DC-based renewable energy sources in large-scale systems—a crucial step toward achieving grid decarbonization targets. In this context, a reliable DCT with smooth bidirectional power flow capability is required to interface various distributed energy resources (DERs). In this regard, a 1 MVA DCT prototype has already demonstrated in the power electronics laboratory (PEL), and validated under unidirectional power flow operation.

Project Objectives:

Enabling bidirectional power flow capability in the mentioned DCT case requires firmware and control modifications and improvements. Meanwhile, validating the control implementations required in this regard in a safe hardware-in-the-loop (HIL) setup is advantageous. Therefore, the motivation and primary goal of this project are to prepare the HIL setup by implementing an accurate model of the DCT hardware and utilizing the same control system used in the real 1MVA DCT prototype. Subsequently, implementing firmware and control adaptations on the DCT controller and validating the bidirectional power flow capability of the converter by determining proper scenarios in the HIL model. In what follows, a detailed list of project tasks and expected steps is summarised.

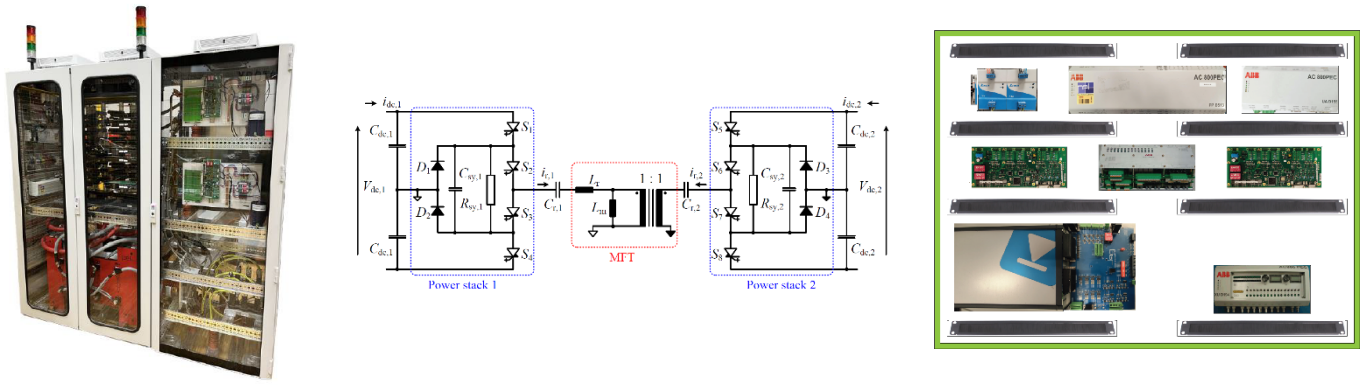

Figure 1. *Left: The photograph of the 1MVA DCT prototype. Center: The Topology of the DCT converter. Right: Illustration of the HIL setup building blocks.*

- Finalizing the available general-purpose RT-HIL setup in the lab
- Modelling of the DCT case study in the PLECS RT-box HIL platform
- Mastering the Power Electronics Controller (PEC) ecosystem of the ABB, used in DCT control, and understanding the working principles of the DCT converter
- Implementing a power reversal method and modulation technique on the existing control of the DCT and verifying the DCT's bidirectional operation
- Finalizing the project by preparing a simple graphical user interface (GUI) of the DCT controller with the implemented modifications

Prerequisite knowledge:

- Power electronics DC-DC converters
- Resonant conversion
- PWM schemes
- PLECS RT-box platform

Available equipment:

- All the equipment required to fulfill the project's goals, such as the PEC controller, RT-box, and HIL platform, etc.
- No hardware development is needed

Methodology and foreseen steps of the project:

- Limited hardware implementation and assembly
- Modeling
- Control implementation
- Analysis
- Optimization (if required)

Student gain:

- Learning about the steps of preparing a HIL setup for power electronic-based systems
- Modeling of power electronics systems in PLECS for Real-Time simulations
- Mastering an industrial controller (PEC), programming with embedded code support in MATLAB
- Acquiring the DCT converter principles and their basic operation in future MVDC grids

References:

- R. Wang, N. Djekanovic and D. Dujic, "Design of a Megawatt-Scale IGCT-Based Medium-Voltage Direct Current Transformer," in IEEE Transactions on Power Electronics, vol. 40, no. 8, pp. 11616-11627, Aug. 2025, doi: 10.1109/TPEL.2025.3557267.