Master's Thesis Engineering Technology

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Validation of Different Power Loss Models for a Bidirectional Isolated Dual-Active-Bridge DC-DC Converter used in Ultra-fast, Modular Electric Vehicle Chargers

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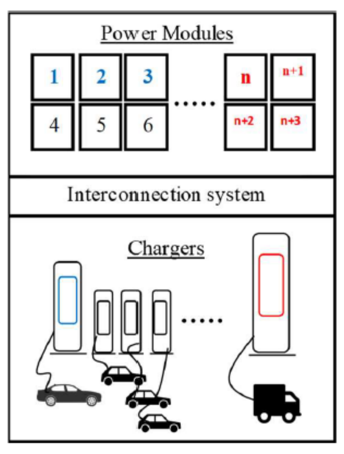
Introduction

Energyville in Thorpark, Genk conducts research on Electric Vehicle chargers, in particular the use of **350kW DC chargers** with modular construction. Such modularity allows chargers to adapt to the specifications of the battery, making the charging itself more efficient and allowing the battery to last longer. These modules contain a **Dual Active Bridge converter** (DAB) and consists mostly of MOSFETs, diodes and a galvanic isolation. The output power can be set as desired when connecting the modules in different ways. In order to fall under the category **Ultra-fast charger**, the battery must be at 80% when charging for 15 minutes. To ensure that all EV can be charged, the voltage range must be from 200V to 900V and the current range from 5A to 500A.



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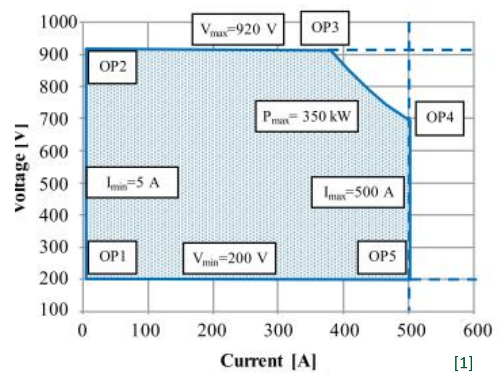

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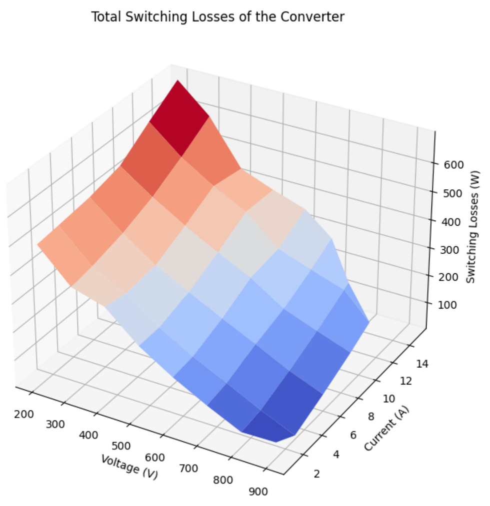
Problem and method

- Because of the **large radius** of cars with fossil fuel, the need for Ultra-fast EV chargers is high. Hereby the **charging time** can be reduced and the radius is not a great issue anymore.
- The problem with the Ultra-fast chargers is that a **high frequency** is required in order to reduce the charging time. With high frequency comes **high switching losses**. These losses are unwanted and pernicious.
- This thesis aims to **recreate and analyse** three models to determine the switching losses. After this, the results of the models are compared with **experimental results**.

Models

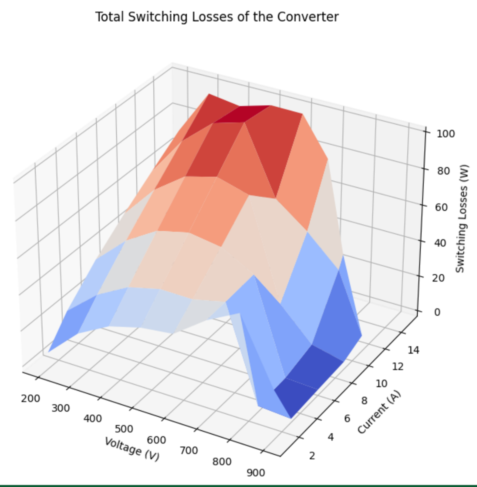
Switching Loss Model 1

- Assumes **linear transition** of the drain to source voltage and drain current.
- **Calculates** the losses with T_{ON} and T_{OFF}, with only **one stage of transition**.
- Models the non-linear behaviour of the **parasitic capacitances** by equating it to a **single value.**



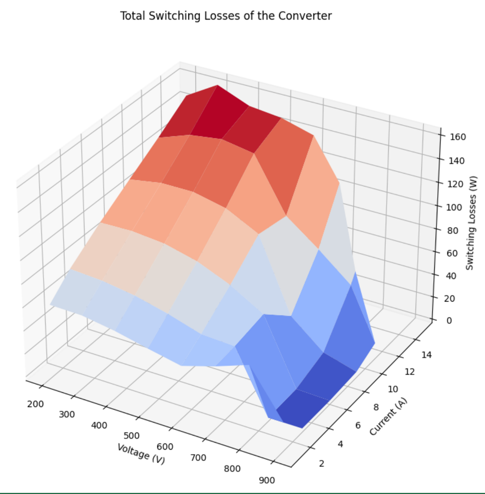
Switching Loss Model 2

- Models the **transients** of the drain to source voltage and of the drain current, then **integrates and calculates** the losses.
- Models the non-linear behaviour of the **parasitic capacitances** by dividing and equating it into **two discrete values.**



Switching Loss Model 3

- Takes into account the **current** for **discharging** the output capacitances.
- Models the non-linear behaviour of the **parasitic capacitances** by equating it to a **single value,** based on the **operating voltage**.
- Takes the reverse recovery losses of the **antiparallel body diode** into account.



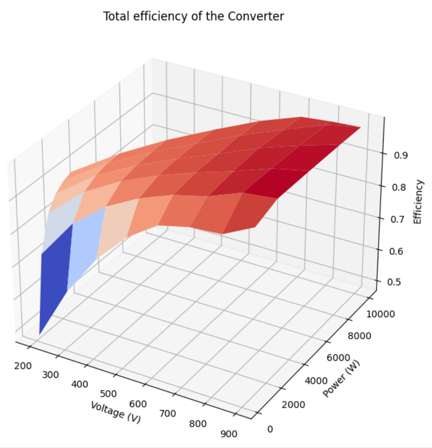
Results

A **converter model** estimates all converter losses over a predefined operating range with each of the three switching loss models. The following losses are returned:

- MOSFET **switching losses** (Primary, secondary and total).
- MOSFET **conduction losses** (Primary, secondary and total).
- Transformer **copper losses**.

Based on these losses, the total **efficiency** of the converter can be estimated over the entire operating range.

The **actual losses** of exceptional operating points in this range were calculated based on measurements from a prototype 10 kW converter. The **accuracy of the models** were verified by comparing the estimated results from the models with these actual values.



Conclusion

Zero voltage switching conditions appear to be met across almost the entire operating range. Assuming the **turn-on losses** to be negligible during those cases can lead to an underestimation of the turn-on losses. Even tough the drain-source voltage and drain-current overlap is almost non-existent, the **reverse recovery losses of the body diode** ensure that the turn-on losses cannot be neglected during zero voltage switching operation.

The most accurate model appears to be **model 3** as it models the behaviour and values of the **turn-off losses** over the entire operating range with surprising accuracy, especially in the **high power region**. However, this model is not perfect, as it grossly underestimates the losses in the **low power, high voltage regions**. For this reason, the use of **model 1**, which greatly overestimates the losses over the entire range, is recommended as its accuracy is better in this area. **Model 2** grossly underestimates the losses over the entire operating area and is therefore not recommended.

The **conduction and transformer losses** are modelled with great accuracy over the entire operating area, especially in the high power regions.

Supervisors / Co-supervisors / Advisors

Prof. Dr. Ir. Wilmar Martinez
Ir. Camilo Suarez

[1] C. Suarez and W. Martinez, "Fast and Ultra-Fast Charging for Battery Electric Vehicles - A Review," *2019 IEEE Energy Convers. Congr. Expo. ECCE 2019*, pp. 569–575, 2019.

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