Tool construction for optimal transformer design

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Background

EnergyVille is a research facility formed by Imec, Vito and the universities of Leuven and Hasselt. The main focus of the group is research in **sustainable energy solutions** and intelligent energy systems.

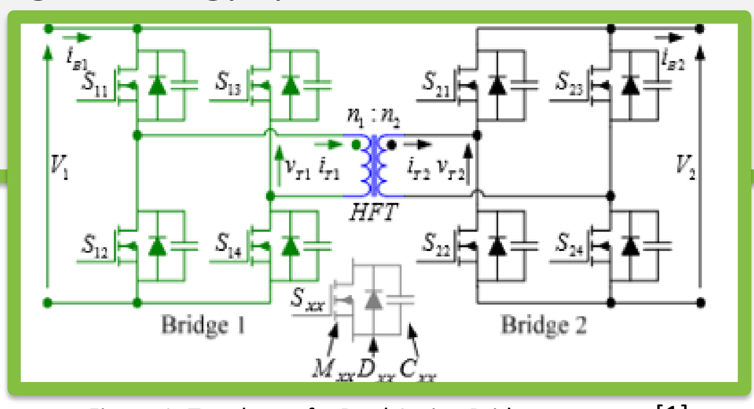

Figure 1: Topology of a Dual Active Bridge converter [1]

One of the studies conducted at EnergyVille looks into the potential of DC for a alternative grid design because of the increase in renewable energy sources. This master's thesis is part of this study and focuses on **high frequency transformer design** (highlighted in blue in figure 1) of a **dual active bridge converter.**

Problems & Goal

- **Designing** a transformer for a specific purpose can take up a long time and effort, which can be **expensive** for the client.
- The demand for electrical systems keeps growing. This will lead to the inevitable **shortage of copper**.
- **Components** of high power electrical applications are sometimes **too large** too implement.

This thesis aims to create a **model** for transformer design optimisation. The model evaluates as many designs as possible. The client can use this as a **tool** to chose the most **appropriate design** for a specific application while taking **the three mentioned problems into account.**

Models

Thermally limited

The first approach takes a **maximum temperature** for the conductors and the core of the transformer into account. Any design which exceeds this threshold is dismissed. In this design, **no cooling** is required, which is interesting **when space is limited**.

Important parameters of the model are:

- 50% core loss and 50% copper loss
- T_{max} is an input (depends on material)

A flowchart of the model is shown below. The code **iterates** through different dimensions and through all available materials.

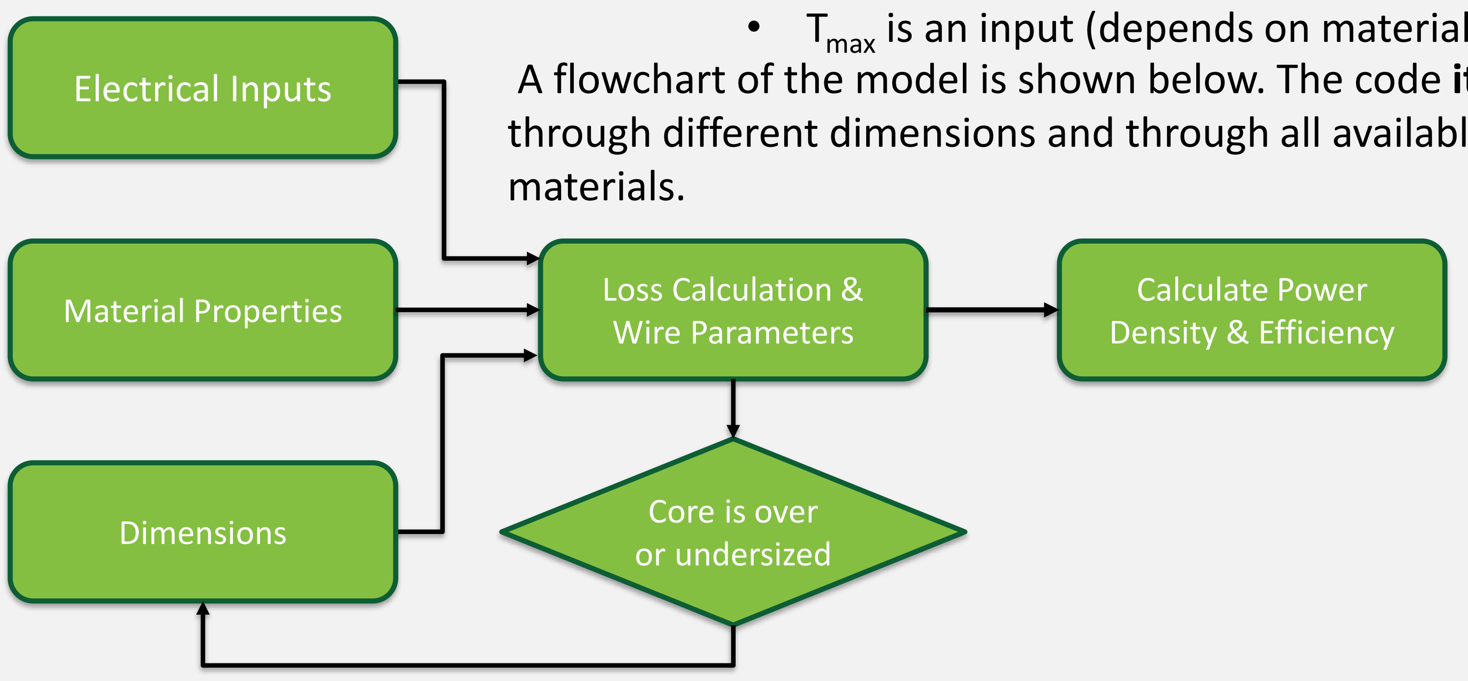

Figure 2: Flowchart of the thermally and non thermally limited models

Non thermally limited

In contrast to the thermally limited model, the theoretical **temperature of the transformer has no limit**, allowing **more and smaller designs to be evaluated**. In practice this means the transformer is combined with external **cooling**, which **increases the cost**.

This approach follows the same flowchart as the thermally limited model (figure 2). The differences are:

- parameters and equations used
- core/copper loss ratio

The temperature rise is recalculated for each size to ensure that the temperature does exceed the **operational limit of 200°C.**

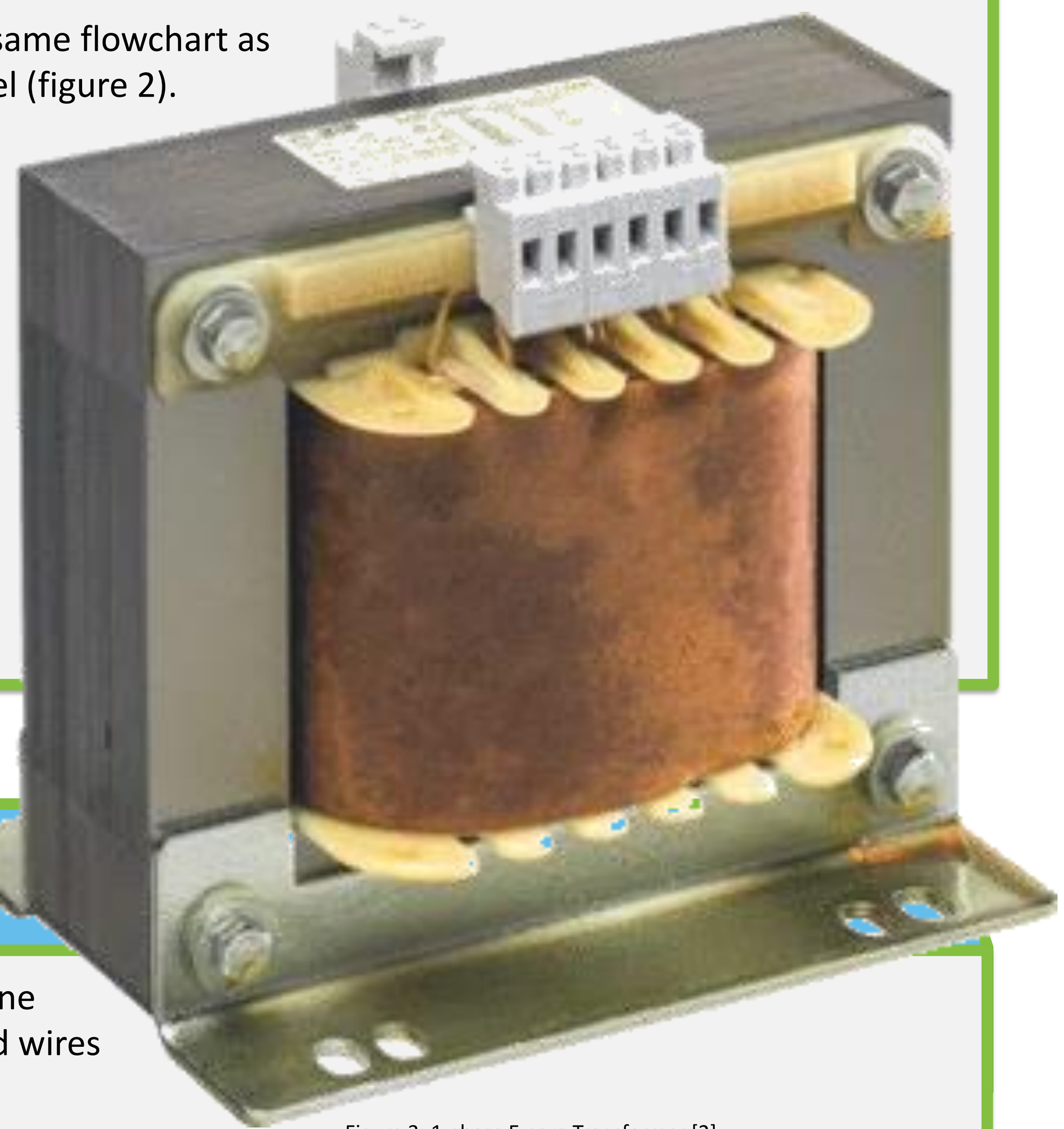

Figure 3: 1 phase E-core Transformer [2]

Results

The code is programmed in **Matlab** but can be translated to any other programming software. The tool serves as a **base** for anyone who wants to design a transformer and can be altered to meet the client's specifications. The losses are only calculated for round wires and Litz wires. The program can be extended by considering different types of wires and comparing the losses accumulated.

After running the code, a **graph** successfully shows the relations between a specific material and its dimensions and the **power density** and **efficiency**. Each dot on figure 4 represents a specific design with blue being thermally limited and red non-thermally limited. The latter model clearly calculated more designs and gives designs with a much higher power density. The designer can weigh up whether to opt for large dimensions with high efficiency or high power density with a somewhat lower efficiency and also compare different materials with each other. The efficiency turns out to be really high (up to 99,9%) which can be expected from a transformer.

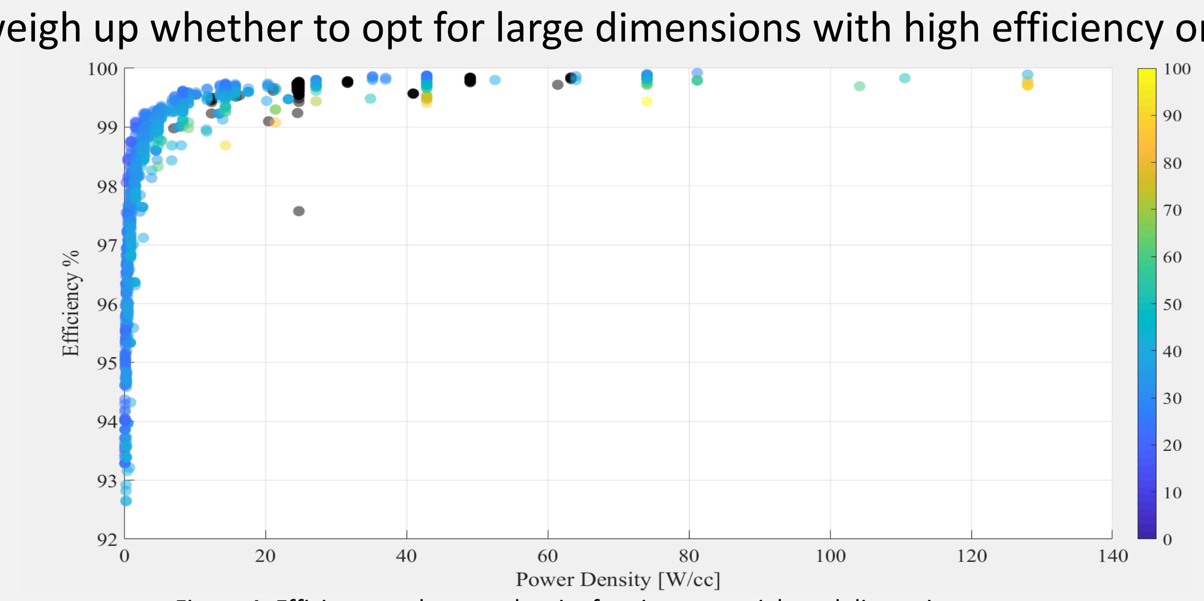

Figure 4: Efficiency and power density for given materials and dimensions

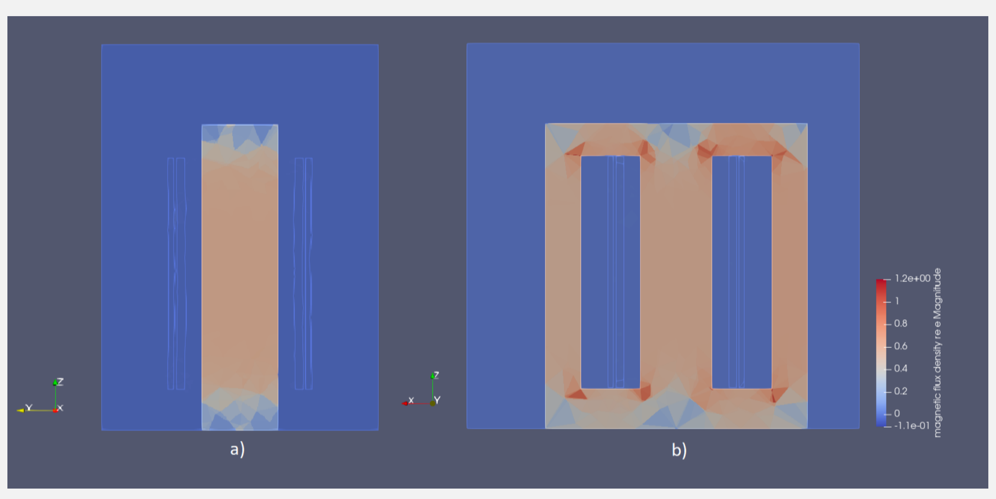

Figure 5: Flux representation in the core: a) cross section of side view, b) front view

Using the **simulation tool**, a visual presentation of the **flux** in the core was successfully displayed, which can be seen in figure 5. The simulation was used to **validate** the results of the code. Using this validation method proved quite useful as certain inconsistencies in the code were found and adjusted. The **final version** of the code is, as a result, more **accurate**.

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[1] K. D. Hoang and J. Wang, "Design optimization of high frequency transformer for dual active bridge DC-DC converter," IEEE, Marseille, France, 2012.
[2] „Elektrobode,"[Online]. Available: https://www.elektrobode.nl/products/eti-ct-nn-voedingstransformator-10574. [Opened 24 February 2020].