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Middle East Technical University

Department of Electrical and Electronics Engineering

# EE464: Static Power Conversion II

# Term Project Simulation Report

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# Introduction

The aim of this project, like the previous semester, is to design a battery charger; however, the difference is that the project should utilize an isolated DC-DC type converter. The design should decrease the DC input voltage to 12V to charge the battery connected to the output by strictly using a closed loop control system. Project specifications are available at the [project GitHub repository](https://github.com/odtu/ee464/tree/master/Hardware%20Project).

In this report, the candidate isolated DC-DC converter topologies for battery charging are discussed, and the corresponding calculations and simulation results regarding the selected topology are displayed. Then, using these results, the components that will be used in the hardware design are chosen. Finally, some measurements related to the initial transformer design gathered after the tests done during the laboratory is presented.

This project is still ongoing and evolving.

# Topology Selection

To control the output current and voltage while achieving high efficiency in this project, a proper isolated DC-DC converter topology should be selected. In this section, several isolated converter topologies are considered and compared to select the most suitable one.

* ***Flyback Converter:*** This topology is one of the simplest designs that can be used in order to design an isolated DC-DC converter. It is advantageous due to uncomplicated design procedure since it only utilizes a single active switch. Moreover, a lower number of components are needed compared to the other types of topologies for this converter. A lower number of components makes sure that the design is cost effective compared to the other types of topologies which is an important advantage of this topology. Also, flyback converter is generally a good choice for low power applications [1] which is smaller than 200W as it is the case for this project.

Apart from several handy advantages, there are multiple disadvantages of this topology as it single-ended type converter which means that it operates at a single quadrant of the BH curve. Also, it charges and discharges the inductors at different switching cycles, a gapped core is essential to increase the energy storage capacity. Thus, the main disadvantage can be poor transformer utilization. Moreover, due to high ripple currents at the input and output sides stemming from low inductance of the gapped core, larger capacitors should be utilized which is also a disadvantage for this topology.

* ***Forward Converter:*** This converter is mainly used for medium power applications in practice. One of the best advantages compared to the flyback is that the energy does not need to be stored as it is transferred in at the same cycle that is created. Thus, the magnetic core can be gapless, and the transformer utilization is better [2]. Using a gapless converter reduces the current ripple; thus, efficiency can be increased, and smaller rating components can be used which will probably lead to more compact design compared to the flyback converter.

The drawbacks compared to the flyback converter can be the increased cost as it uses an extra diode and an inductor, which is an important issue for low-budget projects. Moreover, as the energy is transferred for the same cycle, magnetizing current should be reset before the nest switching cycle which limits the maximum duty to 50%. If the transformer is not properly designed and controlled, higher duty cycle than 50% will lead to saturation of the core which makes a sensitive control system a must for this topology. Also, in the practical design, a third winding is added to protect the circuit from the leakage inductance effects. However, due to this winding, voltage across the primary switch is increased which results in higher voltage stress across the switch which is an important disadvantage which needs to be handled.

* ***Push-pull Converter:***The main application area consists of higher power applications since the power is distributed and handled by two active switches. Also, this topology differs from the previous two as it is double-sided which implies that the transformer is operating at two quadrants of the magnetic core which results in better utilization of the transformer. Therefore, this is a good choice for high power applications due to high efficiency.

However, due to the increased number of active switches, the total cost of this topology is fairly high compared to the other two. Also, control of these two active switches is more complex since the dead time should be arranged properly in order not to short circuit the source at the input. Moreover, a center-tapped transformer is used in this topology; thus, overall, the design procedure, when two active switches and transformer design is considered, is more complex. Finally, when two switches are off, voltage stress across the two switches are still quite high which may cause problems when the switch is not properly selected and cause heating problems as well as increased losses due to possible high on resistances.

* ***Half-bridge and Full-bridge Converters:*** These two topologies are also used for high power applications, generally higher than push-pull converters. The advantage of these two compared to the push-pull converter is that the voltage stress across the switches is decreased. Moreover, these are also double sided; however, they have single primary winding which makes sure that the transformer is utilized better compared to the push-pull converter [2].

The disadvantage of these topologies is that half-bridge cost is slightly more than the push-pull converter. For the full-bridge converter, the cost is considerably higher as it includes 4 active switches which also complexes the design and the controllers. These topologies become an overdesign for low power applications.

When all the topologies are considered, for low power application which is the case for this project, push-pull, half-bridge and low-bridge converters are found to be overcomplicated for this specific application. Also, as the cost and complexity are important points for this project, flyback converter topology is found to be applicable and sufficient. In the nest section, a flyback converter will be designed and presented.

# Validation of Design

# General design

# Analytical calculations

# Simulation results and validation

# Component Selection

# Initial Transformer Tests

# Aimed Bonuses

In terms of the bonuses, efficiency, analog controller IC, PCB, and compactness bonuses are aimed. The efficiency is aimed to be as high as possible while achieving at least 80% efficiency to avoid negative points. The controller will primarily be implemented as an analog controller. In case the analog controller does not work, digital controller will be utilized by giving up for the bonus. Also, this semester, the project will try to be implemented on a printed circuit board to gain bonus points both considering the PCB and compactness bonuses. If the project is implemented successfully, a box can be designed to have a better-looking project and gain some bonus points.

# Future Work

As mentioned before, this project is under construction. After the feedback presentations, we will finalize our tests and transformer implementation as well as the overall project. Until the demo day. The hardware project will be implemented as soon as possible so that the tests will be conducted on the implemented design to eliminate the errors faster to finalize the project for the demo day. The closed loop control will try to be implemented using an analog controller; however, if it does not work during the tests, the same system will be implemented using a digital controller. Overall design and the design particulars will be explained broadly in the final report.

# References

[1] ElMenshawy, M., & Massoud, A. M. (2022). Medium-Voltage DC-DC Converter Topologies for Electric Bus fast charging Stations: State-of-the-Art Review. *Energies*, *15*(15), 5487. <https://doi.org/10.3390/en15155487>

[2] *EE464-Static Power Conversion-II*. (n.d.). <https://keysan.me/presentations/ee464_power_supplies.html#91>