SiC Based Power Converter for Industrial Induction Hardening of Steel Probes

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Abstract

This article describes the design and start-up of a SiC-based power converter topology for induction heating applications. This converter is conceived as a versatile tool for further research activities on the new heating processes currently demanded by the metal industry.

Introduction

Induction heating (IH) processes stand out for their velocity, durability, and ease of control [1]. Moreover, the main advantage is that there is no need to heat the whole piece, instead, only the part that is being treated. Consequently, the efficiency of the process increases. For these reasons, IH is becoming the main heating technology in the modern metal industry. Nowadays, the metal industry is demanding improved heating processes, which expand the boundaries of current IH applications. New processes require lower frequencies or higher currents, among others. Research and development of new processes require power generators with the commented capabilities.

Many power electronics topologies are used in IH systems [2,3]. The decision to use one topology or another depends on several parameters such as frequency and rated power. Those power converters, in general terms, adapt the mains' frequency to the frequencies required by the IH process.

Most of the IH technologies make use of resonant circuits [4] in the inverter stage, to reach high frequency and efficiencies.

This work describes the design of a versatile power electronics arrangement intended for testing a high variety of IH processes.

Induction heating power converter

Ikerlan is working on a test bench that will be used to carry out heat treatments of steel billets with different geometries, rated powers, and frequencies. For this purpose, a versatile power converter has been designed to feed the inductor. The design is based on some previous projects of the technology centre. The converter used in those projects has been adapted to the induction heating system (Figure 1).

Topology description

This power converter is divided into three main stages. A controlled 3-phase rectifier generates the dc voltage up to 650 Vdc. The rectifier is followed by two paralleled DC-DC buck converters that will further reduce the voltage of the first dc bus. In the last stage, the H-Bridge inverter is used to feed the inductive load that can be configured in two ways: paralleled half bridge or full bridge, depending on the application's requirements. This last stage is directly connected to the load (RL) and the capacitor bank (C), altogether forming an RLC resonant circuit.

All the semiconductors are Silicon Carbide (SiC) devices: CAB425M12XM3 by CREE. They have low inner inductance, and their terminal layout eases to reduce parasitic inductances when designing busbars. CGD12HBXMP commercial drivers from the same manufacturer are used.

Start-up of the designed prototype

The designed power converter has been assembled and step-by-step verified before starting its normal operation.

First, the rectifier stage has been validated. It has been connected to a 3-ph source and verified that the output voltage is set to the reference value. In this way, the correct control of the rectifier has been confirmed. Even more, the right quality of the power has been assured not to introduce so much noise to the mains.

Next, the voltage in this first dc bus has been reduced in the DC-DC stage. It has been observed that different voltage references have been correctly followed with the proposed control.

Regarding the resonant inverter, semiconductors switch with a duty cycle of 50 % and a fixed frequency in the tests. This frequency must be slightly bigger than the RLC circuit's resonant one to guarantee inductive operation mode.

Finally, the whole converter has been tested. Despite the previous steps have been carried out with commercial voltage sources, in this test the rectifier has been connected directly to the mains. Some results are presented in Figure 2. These results validate the suitability of this converter for the investigation of new IH processes as one shown in Figure 3.

Conclusions

In this work, a complex SiC-based power converter for induction hardening has been implemented. This prototype converts the mains voltage into a high-frequency current which is needed to feed the inductor.

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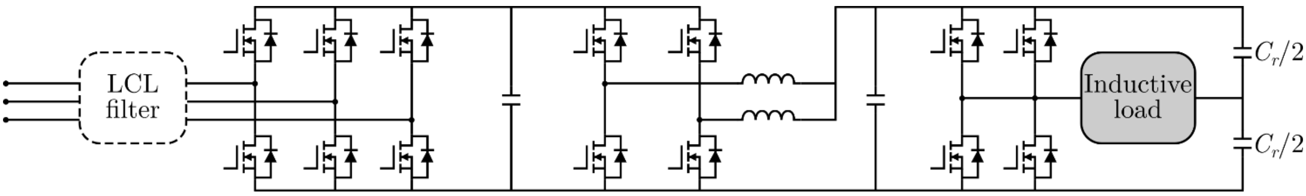

Figure 1. Induction heating power converter topology.

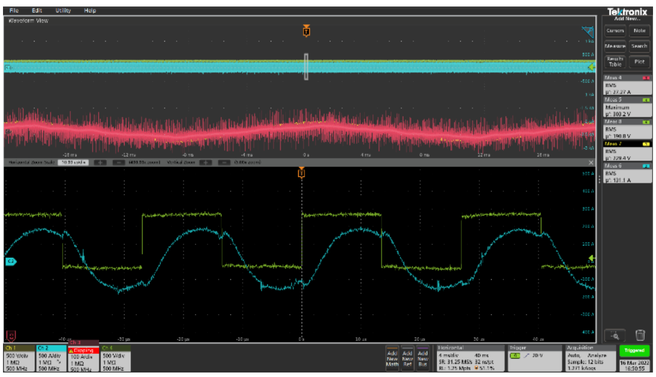

Figure 2. Current (blue) and voltage (green) in the resonant tank, for the paralleled half-bridge configuration of the inverter.

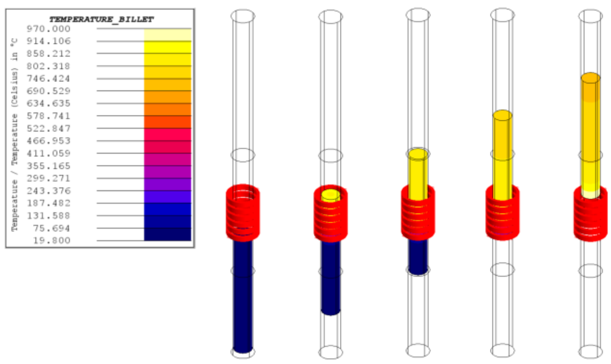

Figure 3. FEM 3D simulation: temperature evolution of induction hardened cylindrical workpiece.