Performance Comparison of Single-Phase Cycloconverters with SiC Transistor and IGBT with Different Control Strategies

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***Abstract*—Silicon Carbide (SiC) MOSFET devices exhibiting several advantages, including high blocking voltage, lower conduction losses, and lower switching losses, when compared to silicon-based devices have become commercially available, enabling their adoption into power supply products. This paper presents a novel approach to designing a cycloconverter using SiC MOSFETs as opposed to the conventional usage of IGBT. A comparative study is attempted between the two with respect to power loss, system efficiency, leakage current etc. Furthermore, different closed loop control strategies are used to control the speed of an induction motor using the SiC cycloconverter model designed in this paper. MATLAB/Simulink models and simulations are used to analyze the results for the above.**

***Keywords—*Cycloconverters, IGBT, Silicon Carbide MOSFET, PID controller.**

# INTRODUCTION

Wide-bandgap (WBG) based semiconductors such as Silicon Carbide (SiC) or Gallium Nitride (GaN) are ready to carve out a niche in applications that demand the ability to work at high voltages and temperatures while demonstrating high efficiency and relatively smaller dimensions owing to their intrinsic properties. These WBG based semiconductors offer several advantages over the equivalent silicon devices available in the market today, few of which include, lower leakage current, significantly higher operating temperatures, better conduction and switching properties. For these reasons, the WBG devices have been identified to have a promising future in the power semiconductor industry.

In this paper however, we mainly focus only on the Silicon Carbide based Power devices. There has been a tremendous amount research effort on developing power semiconductor devices with Silicon Carbide (SiC) in the pursuit of higher efficiency and smaller dimensions [1], [2]. The availability of SiC wafers on a commercial basis has led to the demonstration of many types of metal-oxide semiconductor (MOS)-gated devices that exploit its unique properties. These emerging Silicon Carbide (SiC) MOSFET power devices promise to displace Silicon IGBTs from the majority of challenging power electronics applications by enabling superior efficiency and power density, as well as capability to operate at higher temperatures [3]. Reference [4] focuses on the comparison of a SiC based DC/DC converter and an IGBT based DC/DC converter and thus concludes that the efficiency of an SiC converter is greater than that of the IGBT converter over an output power range. An electro-thermal analysis of an automotive traction inverter platform based on SiC MOSFET and SiC IGBT technology is discussed in [5] and the results show that there is a higher total loss reduction in the SiC MOSFET model compared to the IGBT model.

A Cycloconverter refers to a frequency changer that can change AC power from one frequency to AC power at another frequency. A Cycloconverter is a device that converts constant voltage and frequency AC waveform to another AC waveform of lower frequency without using DC link in the conversion process thus making it highly efficient. Cycloconverters are extensively used for driving large motors like Rolling mills, water pumps, variable frequency speed control for machines such as Induction motor, Industries etc. Blocking mode type and Circulating mode type are the two main types of Cycloconverters. In Blocking mode, depending on the polarity of the load current, either the positive or negative converters are enabled. The blocking mode operation has some advantages over circulating mode operation as they don’t need any integroup reactors (IGR) reactors hence size and cost is less. The speed control of induction motor plays Important role in industries, there are various ways to control the speed of motor but considering it’s efficiency, this paper proposes a Silicon carbide based Cycloconverter for the single phase induction motor speed control. A single-phase to single-phase Cycloconverter consists of two full wave converters that are linked back to back.

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5. A. Kempitiya and W. Chou, "An electro-thermal performance analysis of SiC MOSFET vs Si IGBT and diode automotive traction inverters under various drive cycles," 2018 34th Thermal Measurement, Modeling & Management Symposium (SEMI-THERM), San Jose, CA, 2018, pp. 213-217.

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