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 of 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. For all these reasons, in this paper, we are designing a cycloconverter using a SiC MOSFET as opposed to the usage of IGBT in doing the same.

In a cycloconverter, a constant voltage and frequency AC waveform is converted into another AC waveform of lower frequency without using DC link in the conversion process thus making it highly efficient [6]. A single-phase to single-phase cycloconverter consists of two full wave converters that are linked back to back. Cycloconverters are extensively used for driving large motors like rolling mills [7], water pumps, variable frequency speed control for machines like induction motors etc. Blocking mode type and circulating mode type are the two main types of cycloconverter [8]. The speed control of induction motor plays an important role in industries, there are various ways to control the speed of a motor but taking its efficiency into consideration [9], this paper uses the Silicon Carbide based cycloconverter for the speed control of a single phase induction motor using PID control strategy.

The objective of this paper is to design an efficient cycloconverter using SiC MOSFET and compare the performance of that with a cycloconverter designed using IGBT. The forthcoming sections give a better understanding of the above. Section II focuses on modeling the SiC MOSFET using MATLAB/Simulink. Design of the cycloconverter using the SiC MOSFET is discussed in section III. Section IV gives a brief understanding about the PID Control strategy and its use in the speed control of the induction motor by controlling the operation of the cycloconverter designed using the SiC MOSFET. Section V analyses all the simulation results and compares the performance SiC MOSFET and IGBT pertaining to various characteristics such as power loss, system efficiency, leakage current etc. Finally in section VI all the main results are concluded.

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