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CONTROL OF DIRECT MULTI-INPUT MULTI-OUTPUT (MIMO) USING SINGLE-PHASE MATRIX CONVERTER (SPMC) TOPOLOGY

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ABSTRACT

There are numerous studies demonstrating the practical applications of power electronic converters. There are four types of converters, DC-DC, AC-AC, AC-DC, and DC-AC energy conversion. A Multi-Input Multi-Output (MIMO) converter allows users to input from various sources and thus utilize them in different loads. A typical MIMO converter circuit topology use separate converter circuits to perform energy conversion operations. This contributes to the increase in semiconductor devices, which leads to a bulky size. It also contributes to high power semiconductor losses and low power density. The space constraint remains a serious concern for developing the power electronic converters for floating offshore oil and gas platforms. While there is an ever-increasing concern to improve the power density for sustainable electrical energy has encouraged efforts to improve the power density of the electrical power converters. Hence, in order to meet the requirement of enhancing power density and minimizing the size of power electronic converters for different purposes such as sustainable energy technologies and effective energy production in offshore oil and gas platforms, a novel design and integrated switching algorithms of the MIMO power converter system using a Single-Phase Matrix Converter (SPMC) topology were proposed in this study. Using the SPMC, a single circuit can perform energy conversions for DC to AC, DC to DC, AC to DC, and AC to AC operations. Initially, the computer simulation software of MATLAB/Simulink is used to evaluate and analyse the converter's operating behaviours and characteristics. Three load models were simulated using pure resistive, R load, and inductive, RL loads without and with the safe-commutation technique. The proposed safe-commutation strategy can solve the commutation problems due to inductive load. The knowledge gained from the computer simulation model can help to develop the experimental test rig for the proposed circuit. Next, the development of the experimental test rig of the proposed work has been presented with digital control using Arduino Mega for controlled rectifiers, AC regulators, inverter, and DC chopper operation, including the safe-commutation technique. Nine switches selector controlled the proposed MIMO power converter operations using the SPMC topology were discussed in this thesis. The proposed MIMO power converter has been validated regarding electrical circuit operations through a computer simulation model and a laboratory test-rig. The utilization of the SPMC topology in the proposed MIMO power converter offers a promising opportunity to enhance sustainable energy technologies by improving power density and minimizing semiconductor usage, leading to a smaller environmental impact. Its application to floating offshore oil and gas platforms could also lead to more efficient energy production and reduced operational costs. Furthermore, the proposed safe-commutation technique can improve the reliability and safety of power electronic converters in various industrial and residential applications, leading to a safer and more sustainable energy infrastructure. In this light, this study has successfully theoretically developed, conceived, and realized the proposed MIMO power converter using SPMC.

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INTRODUCTION

1.1 Introduction

The transformation of the manufacturing sector will enable the manufacturing industry to shift to Industry 4.0 and contribute to Malaysia’s commitment to supporting Goals 9 and 12 of the United Nation’s Sustainable Development Goals (SDGs) [1]. This is in line with the Eleventh Malaysia Plan's (RMK-11) 7th Core Blueprint, which emphasises infrastructure strengthening through efficient energy sourcing and delivery to ensure energy sustainability and boost Malaysia's long-term competitiveness [2]. High power supply efficiency and availability are required based on the world's manufacturing landscape's rapid evolution.

This pattern represents the increased use of the power electronic converter system to provide loads with clean and reliable power [3]-[5]. Increased converter power density is the current trend in power electronics converters, particularly for IT applications, where rapid advances in integrated circuit technology have led to more compact systems with increased power consumption [6]. Since the 1970s, the power density of power electronic converters used in various applications has roughly doubled every ten years. Using smaller volumes reduces capital spending on building infrastructure and helps achieve greater design freedom. This development parallels the recent development of power electronic converters moving to the embedded in the final application. This results in lower installation costs and higher electromagnetic compatibility.

The requirements for lower weight, lower production costs, lower volume, and higher efficiency characterise this continual development trend. The relationship of the converter volume, weight, cost, and power loss to the output power is defined by Figures of Merit (FOM), as illustrated in Figure 1.1.