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Full Length Article

# An isolated/non-isolated novel multilevel inverter configuration for a dual three-phase symmetrical/asymmetrical star-winding converter

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ABSTRACT

This article is devoted to the development of a novel isolated/non-isolated multilevel inverter configuration for a dual three-phase star-winding converter. The proposed topology fits the (low-voltage/high-current) applications of medium-power, AC tractions and More-Electric Aircraft (MEA) propulsion systems. The power circuit module consists of voltage source inverters (VSIs) with isolated/non-isolated DC supply. Further, each single phase of the VSI is introduced with one bi-directional switching device (MOSFET/IGBT) and two capacitors with linked neutral points. Also, an original modified single-carrier five-level modulation (MSCFM) algorithm is developed in this article that easy to implement in real digital processors. The proposed modulation algorithm generates 5-level output voltages at each terminal of the VSI as equivalent to standard multilevel inverters. The observed results are presented by numerical modeling of the complete AC converter system with (Matlab/PLECS) simulation software. The investigation confirms that the results are in good agreement with the developed theoretical background and the proposed multilevel inverter is applicable to asymmetrical and symmetrical dual three-phase star-winding converter configurations.
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## 1. Introduction

Multiphase AC drives are the solutions for limited rating devices (MOSFET/IGBT) configuration than their counterpart three-phase AC drives as proven by many literatures and applications [1–6]. Advantage includes the redundant structure, limited DC link ripple, increased power density, fault tolerance, and reduced per-phase of inverter rating [1,2,7]. Recently, the dual three-phase (six-phase) drives of multiphase configuration are preferred due to the high reliability and fault tolerance capabilities [2–6,8–11]. Renowned for its construction, two adjacent phases are spatially shifted by 30° (asymmetrical type) [2–6] or by 60° (symmetrical) [2,8,9]. Application suits solutions for low-voltage/high current AC tractions and More-Electric Aircraft applications (MEA) [12–15]. With MEA propulsion systems, the hydraulic and pneumatic actuators are replaced by multiphase AC drives, which lead to increased reliability in fault conditions and improved overall aeronautic propulsion [13,14]. Both motoring and generator action during start and flight modes are performed by multiphase AC drives [15].

On the other hand, the viability of AC drives is improved by the introduction of multilevel inverters (MLIs). The benefits of MLIs are reduced total harmonic distortion (THD), lowered dv/dt, and the possibility of obtaining high power ratings with voltage-limited devices [16,17]. The combination of both multi-phase and multi-level inverters is an effective solution for increasing power ratings of voltage- and current-limited devices [3–6,8–12,18–23]. However, MLIs are subject to different potential anomalies, (31–37.9)% of failures occurs due to power parts (IGBT mechanisms) and failures addressed with capacitors and gate control techniques [7,24,25].

Classical voltage source inverters (VSIs) are reliable and reconfigured as standard solutions for dual three-phase AC drives, configured by the proper arrangement of multiple VSIs [2–6,8–12,18–23]. Topologies generally are addressed as the dual three-phase inverters (six-phase) for both asymmetrical and symmetrical versions. The VSIs (two-level) are connected at the open windings of a six-phase system and termed dual three-phase inverters [2–6,8–12,18–23]. Each pair of 2-level VSIs is modulating to obtain three-level output voltages. But dual inverters suffer from the restricted levels in the output voltages; each leg is limited to three

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levels and the output voltages appear in three levels in lines, which cannot be overcome with the addressed topologies [2–6,10–12,18–23]. Such configurations are addressed for limited common-mode components and for increasing the output levels [11,19,26]. Also, these topologies are constructed by open-winding configuration or by increased switches per phases or cascading multiple VSIs [10,11,20–23]. Hence the reliability is limited, low redundancy, and complex pulse-width modulation (PWM) strategies are required. However, proper and optimal switch configuration for more than three-level outputs for multiphase AC drives is still not addressed.

Motivated by the above facts, this work proposes a novel configuration for a dual three-phase multilevel (symmetrical/asymmetrical) inverter for both isolated (shown in Fig. 1) and non-isolated (shown in Fig. 2) versions [7,13–17,27]. Moreover, this configuration meets the optimal switch requirements and fits for star-winding loads, medium power (low-voltage/high-current), and MEA applications. The reconfiguration includes each phase incorporated with a bi-directional switch (IGBT/MOSFET), and two capacitors are introduced in neutral linked. An additional benefit is that each VSI outputs 5-level in their line-to-line irrespective of a non open-winding structure. Overcomes, the drawbacks of standard dual inverter configurations available in the literature. Further, the structure is easily extendable to 9, 12, or a higher number of phases. The benefits are compromised the same as for standard multilevel inverters, additionally more reliable under faulty conditions when one or two or more phases fail [2–6,10–12,18–23,26]. Also, an original modified single carrier five-level modulation (MSCFM) algorithm (independent) is developed in this paper and applied to both non-isolated/isolated dual three-phase converters [27–32]. To verify the effectiveness of the proposed converters, the complete system is numerically modelled by Matlab/PLECS simulation software

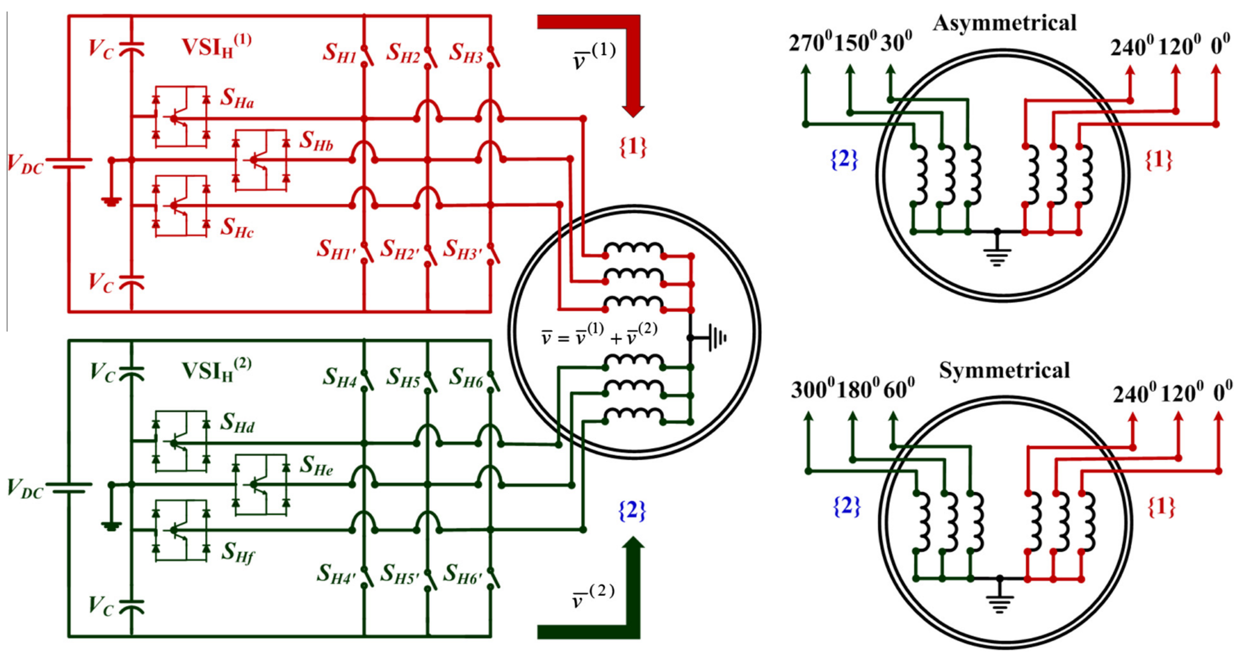


**Fig. 1.** Configuration of proposed novel isolated multilevel inverter for asymmetrical/symmetrical dual three-phase AC drives.

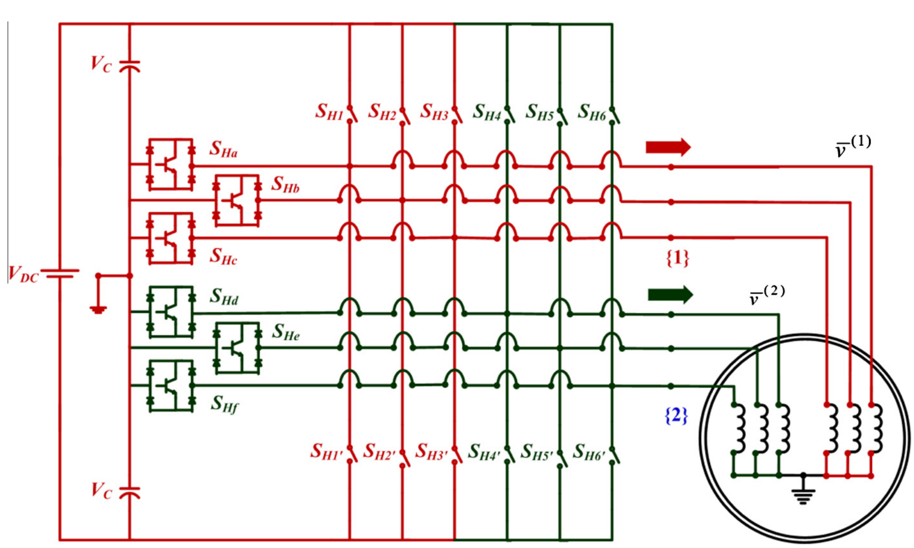


**Fig. 2.** Configuration of proposed novel non-isolated multilevel inverter for asymmetrical/symmetrical dual three-phase AC drives.

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