A MODIFIED HARMONIC ELIMINATION METHOD WITH A WIDE RANGE OF MODULATION INDICES FOR MULTI-LEVEL INVERTER WITH UNEQUAL DC-SOURCES

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***Abstract*—This paper presents a novel modulation technique applied in multi-level inverters with unequal DC sources suitable for wide range of modulation indices. This method considers all the possible switching schemes assuming that the power devices in the different converter modulus can turn ON/OFF up to twice per period. Also, a unified approach using Homotopy algorithm is presented to solve the harmonic elimination equations for all various switching schemes. A three-phase seven-level Y-connected cascaded inverter is modeled in this paper. Experimental results indicate that the proposed technique is effective and efficient for harmonic elimination in multi-level inverter with unequal DC sources and the theoretical results are well validated.**

***Keywords* — Harmonic elimination, multi-level inverter, unequal DC sources, Homotopy algorithm.**

I. INTRODUCTION

In recent years, many high-power and medium-voltage drive applications have been installed (Hammond, 1997; Buschmann and Steinke, 1997). Due to their ability to synthesize waveforms with a better harmonic spectrum and attain higher voltages, multi-level inverters have received increasing attention in the past few years (Lai and Peng, 1996; Menzies *et al.*, 1994; Schibli *et al.*, 1998; Peng, 2001).

The well-known multi-level topologies are cascaded H-bridge multi-level inverter, diode-clamped multi-level inverter, and flying capacitor multi-level inverter (Hosseini Aghdam *et al.*, 2007a; 2007b; Holmes and Lipo, 2003). The Multi-level inverter using cascaded-inverters with separated DC sources, hereafter called a cascaded multi-level inverter, appears to be superior to other multi-level structures. This topology presents a structure that is not only simple and modular but also requires the least number of components. This modular structure makes it easily extensible for higher number of desired output voltage levels without undue increase in circuit complexity. In addition, extra clamping diodes or voltage balancing capacitors are not necessary. Also, soft-switching technique can be applied in this structure to avoid bulky and lossy resistor-capacitor-diode snubbers (Hosseini Aghdam *et al.*, 2007a; 2007b).

It is generally accepted that the performance of an inverter, with any switching strategies, can be related to the harmonic contents of its output voltage. Researchers have always studied many novel techniques to reduce harmonics in such waveforms (Holmes and Lipo, 2003; Mohan *et al.*, 2003; Patel and Hoft, 1973; Patel and Hoft, 1974; Buja and Indri, 1977). There are many techniques applied to multi-level inverter topologies (Hosseini Aghdam *et al.*, 2007a; 2007b; Sirisukprasert *et al.,* 2002; Akbari and Gharehpetian, 2005; Chiasson *et al.*, 2004a; 2004b; Guan *et al.,* 2005). In multi-level technology, there are several well-known modulation topologies like (Hosseini Aghdam *et al.*, 2007a; 2007b; Holmes and Lipo, 2003); General Harmonic Elimination technique, Space Vector PWM (SVPWM) and Carrier-Based PWM (CBPWM) technique.

This paper focuses on the general harmonic elimination method with unequal DC sources. This work presents a novel modulation technique applied in multi-level inverters suitable for the wide range of modulation indices. This method considers all possible switching schemes assuming that the power devices in the different converter modulus can switch ON/OFF up to two times per fundamental cycle. That feature can overcome the switching losses problem, as well as EMI problem (Hosseini Aghdam *et al.*, 2007a; 2007b). This technique results in a low total harmonic distortion (THD) output waveform without any need of filter circuits. To solve the harmonic elimination equations, a general method using Homotopy algorithm (Hosseini Aghdam *et al.*, 2007a; 2007b; Guan *et al.*, 2005; Allgower and Georg, 1990; Kuno and Seader, 1988; Wolf and Sanders, 1996; Lee and Chiang, 2001) is presented to define the switching instants of the power devices for all various switching schemes. This method solves the harmonic elimination equations with a much simpler formulation compared to methods like Newton–Raphson (NR) (Sirisukprasert *et al.,* 2002; Akbari and Gharehpetian, 2005) and Resultant theory (Chiasson *et al.*, 2004a; 2004b). This algorithm can be used for any number of voltage levels without complex analytical calculations.

II. CASCADED MULTI-LEVEL INVERTER CONFIGURATION

The cascaded multi-level inverter uses cascaded inverters with Separate DC Sources (SDCSs). This topology synthesizes a desired voltage waveform from independent sources of DC voltages, which may be obtained from batteries, fuel cells, or solar cells. This configuration recently became very popular in AC power supply