Multilevel Inverters

Control Methods and Advanced Power Electronic Applications

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Ersan Kabalcı
Department of Electrical and Electronics Engineering,
Faculty of Engineering and Architecture, Nevsehir Haci
Bektas Veli University, Nevsehir, Turkey

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CHAPTER

Hysteresis control methods

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Oswaldo Lopez-Santos[a], Diego S. Dantonio[a], Freddy Flores-Bahamonde[b], and Carlos A. Torres-Pinzón[c]

[a]*Program of Electronics Engineering, Universidad de Ibagué, Ibagué, Colombia* [b]*Department of Engineering Sciences, Universidad Andres Bello, Santiago, Chile* [c]*Faculty of Electronic Engineering, Universidad Santo Tomás, Bogotá, Colombia*

2.1 Introduction

The new energy scenario has been pushing permanent advances in power electronic converters and control. Academia and industry have both played fundamental roles in developing and integrating power systems for low-, medium-, and high-power applications with high efficiency and reliability. In fact, due to the high penetration of different energy sources and loads (solar, wind energy, energy storage systems, and electric vehicles), a more flexible and dynamic energy matrix has been formed, evolving toward more modular, efficient, and distributed architectures [1]. This is the case of multilevel convereters (MCs), which have emerged in the last years over the classic converters as an interesting solution in high-power applications [2–7].

Currently, MCs are used in many applications, such as solar and wind energy, railway traction, storage technologies (battery, hydropumped), high-voltage direct-current (HVDC) transmission, reactive power compensation, and electromobility, just to name a few [5, 7–15]. Compared to conventional two-level topologies, multilevel converters present different advantages, making them more suitable for high- and medium-power solutions. Among these advantages are better output signal quality, reduced total harmonic distortion (THD), low dV/dt, smaller input and output filters (if needed), higher efficiency, lower common voltages, lower cost, reduced voltage stress in power semiconductors, as well as modularity and scalability. In addition to their proven qualities, important research efforts are focused on improving their efficiency, power density, and cost [2, 7, 8]. In fact, recent advances have been motivated to increase the power density by working with higher frequencies and reaching smaller power units [16–18].

With respect to the control, during the last few decades several techniques have been researched and developed in order to obtain an accurate sinusoidal output voltage waveform in multilevel inverters. As illustrated in Fig. 2.1, the different

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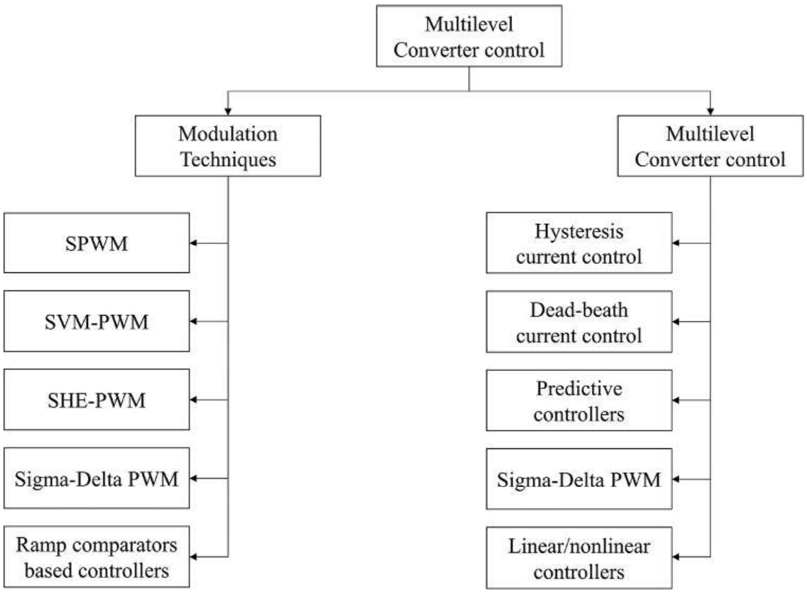

FIG. 2.1

Classification of control methods for multilevel inverters.

approaches can be classified according to two main features: (a) switching frequency, which can be fundamental frequency or high frequency; and (b) control type, which can use one or more closed loops or none [19, 20]. Based on the switching frequency, techniques differentiate fundamental switching frequency and high-frequency modulations. In both cases, it is possible to find the well-known space vector (SVM), sinusoidal PWM (SPWM), and space vector PWM (SV-PWM) modulations. Conversely, the optimized harmonic stepped-wave selective harmonic elimination is limited to fundamental frequency modulation. According to the control technique they use, multilevel inverters can integrate an open-loop scheme using SPWM, SV-PWM, and sigma-delta PWM, in the three cases producing the output signal with off-line computed references. Also, they can use linear and nonlinear closed-loop techniques such as proportional-integral (PI) or proportional-resonant (PR) compensators [21–23], and strategies such as fuzzy logic [24, 25], sliding mode [26], passivity-based [27], and predictive [28]. Although all these techniques present good performance, the more commonly adopted control techniques by industry are SPWM and SVM, because they provide low THD, easy deployment, and robustness [19].

The hysteresis control methods are also widely used in applications of both grid-tie and stand-alone inverters. The basic concept of HC is to switch the output voltage level (for more than two level cases) appropriately if the measured current or voltage goes above or below a given hysteresis band. Implementation of this control technique is simple, since it requires only comparators, as shown in Fig. 2.2 for three-phase systems.

HC has been commonly used in conventional two-level converters showing a high effectiveness, ensuring high power quality in different applications [29, 30].