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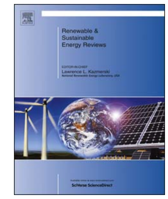

A comprehensive review on reduced switch multilevel inverter topologies, modulation techniques and applications

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ABSTRACT

Recently multilevel inverters (MLI) have attracted more attention in research and industry, as they are changing into a viable technology for several applications. The concept of MLI was introduced for high power and high/medium voltage applications as they can provide an effective interface with renewable energy sources. Developing of reduced switch MLI topology has been a rapid research topic since the past decade, which has not been reviewed so far. Therefore, this review article focuses on the different reduced switch MLI topologies under three categories such as symmetric, asymmetric and hybrid configurations. The important knowledge on these topologies is carefully tabulated based on the three categories in the comparison tables to understand the essential parameters of the MLI topologies. These configurations are not only generating higher voltage levels to improve the power quality but also to reduce the passive filter requirements. Also, this review includes a detailed perspective of various modulation techniques and control strategies for MLI topologies. In addition to that, the different performance parameters of MLI and its calculation methods are discussed with appropriate mathematical expression. This review will help in the selection of appropriate MLI topology for FACTS, motor drives and renewable applications.

1. Introduction

Solar and wind energy are the two major categories of renewable energy sources which have grown extensively for electricity generation. Solar energy has more advantages when compared to wind energy with respect to installation cost, size and maintenance [1]. An inverter is an essential part of any renewable energy power conversion for converting the power from DC to AC. The inverter output can be classified into two types such as square wave (two-level) and quasi square wave (three-level or modified square wave) [2]. Although the square wave and quasi-square wave inverters can be adequate for some viable applications which are still accessible in the market but they are not prescribed to new plans because of its exceptionally low-quality waveform [2,3]. To overcome this drawback, multi-stepped waveform was introduced by the multilevel inverter (MLI) concept. MLI waveform can be divided into two types such as low frequency multi-stepped waveform and high-frequency multi-stepped waveform using pulse width modulation (PWM). Passive filters are essential to obtain a sinusoidal output voltage waveform. High frequency multistep waveform requires less passive filters when compared to other waveforms [3]. The output of renewable energy sources are in the form of DC voltage and inherently unstable [3]. This unstable output of renewable energy sources contribute to the power quality and stability issues in electrical network. To overcome these problems, advanced power electronic converters like MLI are needed. MLI is considered the state of art technology and was started to implement in several applications because of their numerous advantages. MLI comprises an array of power semiconductor device and DC/capacitor voltages which generates output voltage level with stepped waveform [4]. The aim of MLI is to generate a near sinusoidal voltage waveform with several steps by utilizing proper switching signal of the semiconductor devices and isolated or non-isolated DC voltage sources [5]. Increasing the number of level in output waveform leads to attain pure sinusoidal voltage without expensive passive filters and bulky transformers [5,6].

Fig. 1(a) shows the simplified classification of inverter in high power applications. The major classification is direct and indirect. In the direct method, generated supply is directly connected to the load through power semiconductor switch whereas indirect method energy storage component (dc-link) is used in between supply and load. The drawback of the direct method lies in the limitation of its dynamic performance making it less possible to be utilized for high voltage applications. Current source converter from the indirect category is also having the drawback of low power factor and distorted current waveforms [7].

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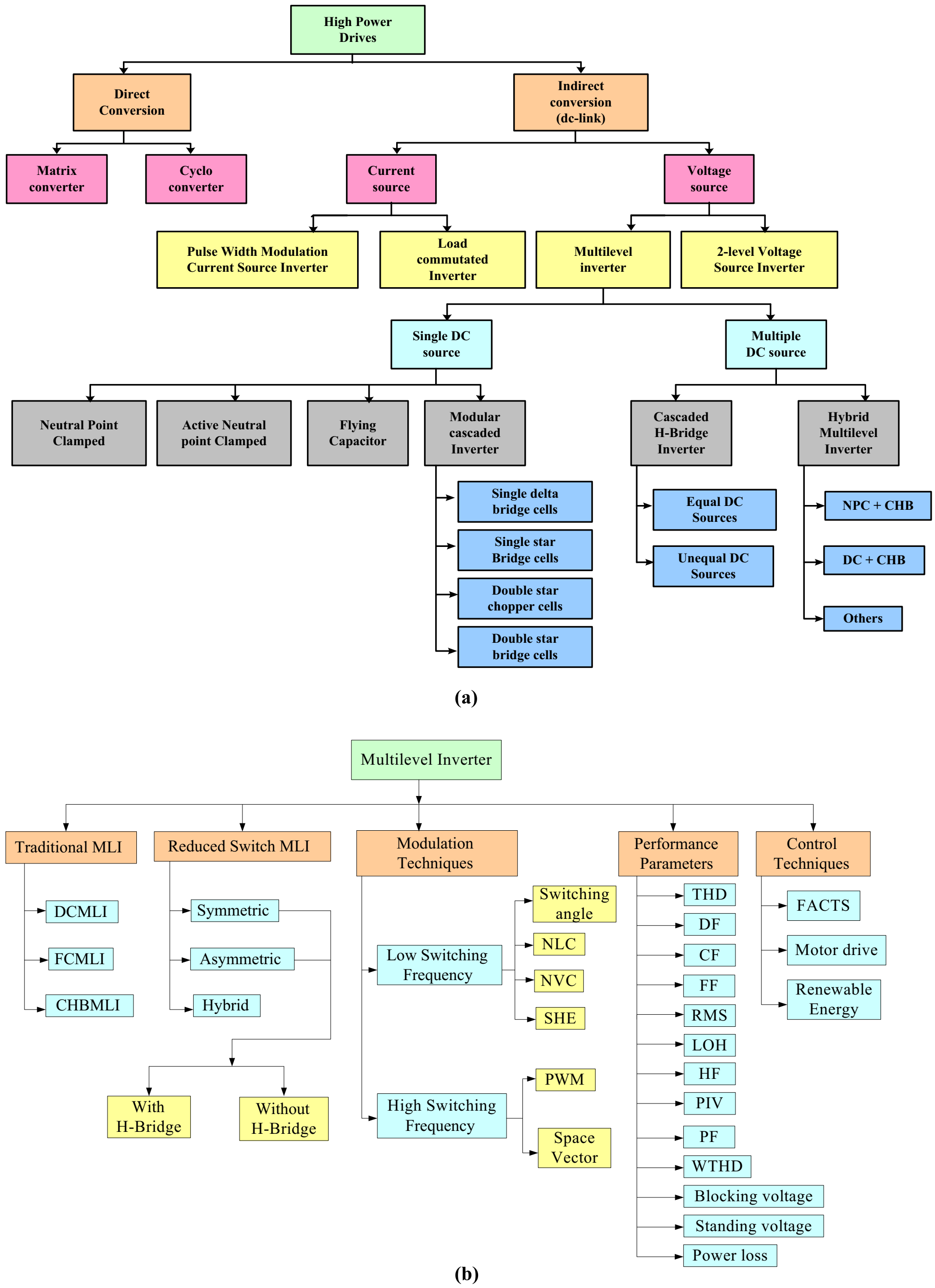

Fig. 1. (a) Simplified classification of High power converters (b) Overall contribution to the review.

Recently, the evolution of new MLI configurations, development of new semiconductor devices and creative modulation techniques have become more imperative for modern power electronics applications. Better efficiency can be achieved in high power applications, by expanding the voltage rating of the system rather than current rating [8]. MLI has the advantages such as better quality output voltage waveform, higher operating voltage ability with lower voltage semi-conductor devices, lower harmonic distortion of output voltage and current waveforms, lesser electromagnetic interference, lower dv/dt stress, reduced requirement of passive filters, lower torque ripple in motor application and possible fault-tolerant operation [9,10]. These benefits contribute to the feasibility of the MLIs for direct integration of medium or high voltage utility grid averting the need for bulky transformers. This is a crucial advantage since this possibility for direct integration of medium/high voltage utility grid is not suitable for a single power semiconductor switch based two-level inverter. A wide range of modulation strategies is involved for triggering the utilization of switches in the MLI topology. The most common strategies are selective harmonic elimination, carrier based pulse width modulation and space vector modulation [11]. The quality of waveform mainly depends on the harmonic profile. The harmonic profile may change based on the MLI topology and modulation strategies [2,3,11,12].

The traditional MLIs are described in the Section 2. Utilization of component count in the traditional MLIs is the major concern while improving the topology. Many new topologies are emerging based on this reduction of component count in the recent days. A review on the conventional MLI topologies for different applications was reported in [3,13,14]. Also, there is no availability of review on reduced switch MLI topologies other than [26], which has only considered ten topologies. Since, the reduced switch based MLI topologies are of great need in the