International Journal of Advances in Applied Sciences (IJAAS)
Vol. 13, No. 2, June 2024, pp. 333~339
ISSN: 2252-8814, DOI: 10.11591/ijaas.v13.i2.pp333-339

Novel cascaded switched-diode five level inverter for renewable energy integration

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Article Info

Article history:

Received Oct 10, 2023
Revised Jan 12, 2024
Accepted Jan 17, 2024

Keywords:

Cascaded multi-level inverter
Full bridge
H-bridge
Multilevel
Sub multilevel inverter

ABSTRACT

This research presents the usage of a unique five-level cascaded switching diode for medium voltage integration of renewable energy sources. Its primary purpose is to decrease the quantity of gate drivers and switches. In addition to that, the cost and space for the installation of multilevel inverters are less. The inverter topology of novel cascaded multilevel inverters and switched diodes will combine both benefits. One-cycle control (OCC), which is used for clock phase-shifting (CPS) to regulate a two-stage container security device (CSD) multilevel inverter of renewable energy integration, was created to address issues with the multilevel inverter's direct current (DC) source variations. The topology also provides efficiency, harmonic distortion reduction, and voltage output quality. Waveforms are created, and a robust resistance to DC source variations is attained. The viability of the unique five-level inverter using cascaded switched diodes is confirmed by discussing the results of both simulation and experiment.

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1. INTRODUCTION

A multilevel inverter's primary function is to convert several direct current (DC) voltage levels into the required voltage. A power electrical device known as a multilevel inverter can use many lower-level DC voltages as input and produce a desired alternating voltage level at the output. Power switches operate at a relatively low frequency, but a multilayer inverter may produce high-quality voltage waveforms [1]–[3]. Several multilevel inverter topologies over the previous ten years were showcased. Furthermore, we have been researching the renewable energy integration system extensively. The multilevel inverter-based renewable energy integration system block diagram [4]. To generate the efficient alternating current (AC) from multiple DC through a novel multi-source cascaded multilevel inverter. A five-level inverter can be made up of four diodes one switching element and two capacitors as a voltage divider. It can control the reactive and real power flow also for a five-level inverter does not require any clamping diode. To achieve the number of voltage levels no transformers are required. A balancing capacitor shares a single DC source [5]–[8]. A five-level inverter can produce an output voltage with five clear-cut levels. Maximum positive voltage (Vmax), maximum negative voltage (-Vmax), two intermediate positive voltage levels, and two intermediate negative voltage levels are among the voltage values included in a five-level inverter. These

voltage levels allow the inverter to generate a clear AC waveform compared to other voltage inverters with a small number of levels. It is a powerful electronic device used in multiple applications [9]–[12].

The main part of renewable energy integration is to maximize the use of clean and sustainable energy while making sure of the reliability, stability, and efficiency of the electrical grid [13]. Cascaded multilevel converters utilize fewer switching components to achieve the same number of output voltage levels as diode-clamped and flying capacitor multilevel inverters. To improve the overall efficiency of a converter and reduce the switching losses by the soft switching techniques. By using the suitable DC voltage source ratio and modulation method the total harmonic distortion (THD) of the output voltage [14]–[16]. To maintain stable and consistent power quality a five-level inverter can help enhance power quality which is critical for a sensitive load and equipment connected to a grid. For monitoring and control with communication interfaces for many contemporary inverters [17]. In a power system, the cascaded H-bridge inverters are developed for voltage regulation, the utility interface of renewable energy, and VAr compensation harmonic filtering. In a cascaded five-level inverter. The harmonic content decreases as the number of output levels rises and also filter circuit is avoided [18]–[20]. In a renewable energy integration, the inverter may intend to work seamlessly with energy storage systems such as batteries. A novel cascaded five-level inverter can effectively convert renewable DC power into grid-compatible AC power. The two-stage cascaded five-level inverter mainly aims to identify the issues related to the DC voltage source, complexity, and switching losses related to the cascaded H-bridge five-level inverter. It is mainly designed and controlled to evaluate the strategy through simulation to imply the advantages for high power applications and middle-high voltage. The second stage of a H-bridge inverter can only operate under power frequency conditions, and it can reduce the switching losses. The control method combines hysteresis losses and carrier cascading modulation [21]–[24]. A cascaded multilevel inverter can produce different output voltage levels. The two-stage cascaded five-level inverter is divided into two stages, here the name itself says that it is two stages. Those two stages are the preceding stage and the backward stage [25].

2. DIODE FIVE-LEVEL INVERTER WITH TWO-STAGE CASCADED SWITCHING

The novel cascaded five-level inverters in the figure aim to reduce gate drivers and the number of switches. Which consists of a bridge inverter, a bidirectional switch, and an auxiliary circuit as well as a metal oxide semiconductor field effect transistor (MOSFET) or an insulated gate bipolar transistor (IGBT). The function of these IGBT is to allow the DC sources to be connected or disconnected from the output. The output voltage is five levels +2vdc, +vdc,0, -vdc, and -2vdc i.e., Vdc refers to each voltage of the DC source as shown in Figure. 1. The CHB five-level topology can be controlled by various pulse width modulation (PWM) techniques such as hybrid PWM, multilevel PWM or SRF14. The five-level topology is a multilevel inverter that can generate five different levels of voltage outputs from two separate DC sources. Auxiliary circuits are used to boost the output of the voltage. CHB five-level topology reduces switching losses, and an improved output waveform can also feed multiple DC loads. The number of switches needed for a N level output voltage, as seen in Figure 1, may be generated by each H-bridge at three different output voltage levels: Vdc, 0 Vdc, and -Vdc.

NIGBT=2Nlevel-2, CHB reduces the number of switches in half as proposed by “Babaei” and “Hossein”. To decrease switch count, circuit size, cost, control, and complexity, a container security device (CSD) topology is created. Two H-bridge cells are needed for a cascade H-bridge multilevel inverter of one phase, and these cells must be supplied with DC voltage sources to generate output waveforms. As seen in Figure 1, the output of two H-bridges is coupled so that the total output equals the sum of the output of each H-bridge cell.

$$\text{Output voltage } (V) = V_a + V_b \quad (1)$$

Here, Va=output of first H-bridge; Vb=output of second H-bridge. In modern days, new multilevel inverters are used to reduce switches in topologies, and related gate drivers are developed. The usual cascaded multilevel inverter and the cascaded H-bridge multilevel inverter are the same. The primary drawback of the cascaded h-bridge multilevel inverter, as seen in Figure 2, is that it requires a larger quantity of switches and associated gate drives, which are expensive and need a complicated circuit. Babei and Hosseini proposed a cascaded half-bridge topology that effectively reduces the number of switches this paper presents the topology of a novel cascaded two-stage CSD five level by using a small number of switches for achieving greater voltage levels. Additionally, under R and L loads, a channel for reverse load currents eliminates voltage spikes. A DC voltage source manufactured by IGBT and its internal diode, which are coupled in parallel to prevent the bridge's shoot-through effect, are shown in Figure 2. For V01 of the main unit 1 we obtained two values that are V01 when switch S11 is turned off and when switch P11 is 0 and

conducts and in between unit 2 and unit 5 the pike removal switch sg is connected. When every switch in the unit is off, the switch SG offers a conduit for the reverse load current to pass. Switch SG will then activate. The first level is represented by the cascade arrangement of all basic units and the spike reduction switch sg in Figure 1. The following is the first stage's maximum output as (2).

$$V_{g=}vo1 + vo2 + vo3 + \cdots + von \quad (2)$$

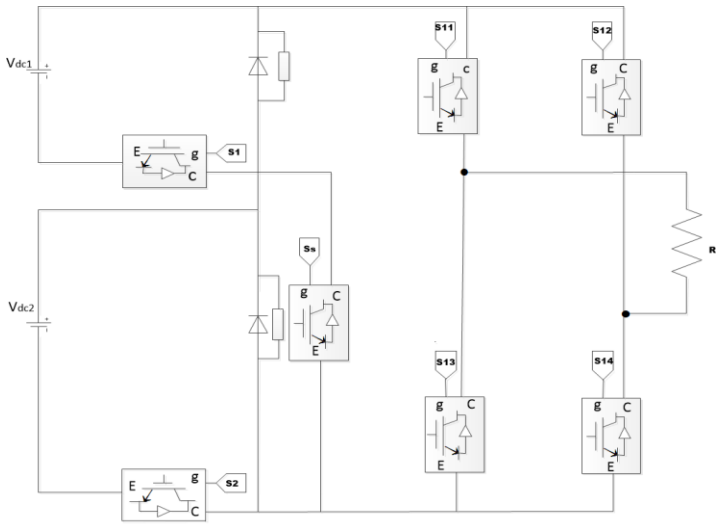

Figure 1. Structure of proposed two-stage cascaded CSD

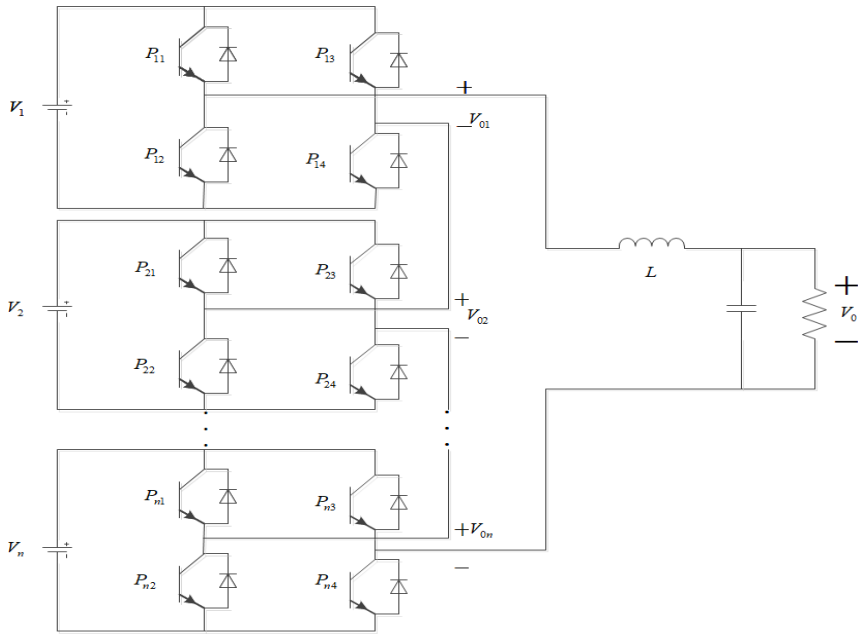

Figure 2. CHB multilevel topology

The waveforms of output voltage produced by the first-stage converters resemble positive staircases. It takes a second-stage converter to provide an output voltage that is both positive and negative. Waveforms of voltage and a positive or negative voltage reference are related to the analysis of switch states. Using a second-stage converter will yield the output voltages' positive and negative halves. In the symmetric scenario, the voltages of all the DC voltage sources equal Vdc. The total number of switches and the N level are the output voltage levels. This may be estimated since NIGBT is required.

$$N\ IGBT = n + 5 \quad (3)$$

$$N\ Level = 2n + 1 \quad (4)$$

The clock phase-shifting (CPS) One-cycle control (OCC) technique diagram for two-stage CSD shows how the output voltage is precisely controlled by adjusting the clock signal's phase. In two stages CSD inverter consists of two stages. The cascaded switching device inverter consists of two stages. A cascaded switching device for a five-level inverter stage. It usually creates a digital view of the desired output voltage. Which is then converted by the inverter stage to an analog voltage. The second stage is the inverter in this analog voltage produced by a cascaded switching device to generate its final output voltage. By manipulating the phase of clock signals, we can control the timing of switches in both the cascaded switching device and the inverter for precise voltage control as shown in Figure 3. According to the table, the second stage implements the positive and negative half cycles of the output waveforms by comparing the reference voltage with zero. The CPS OCC is then constructed for the first stage, and it only corresponds with the positive stage, as seen in Figure 3.

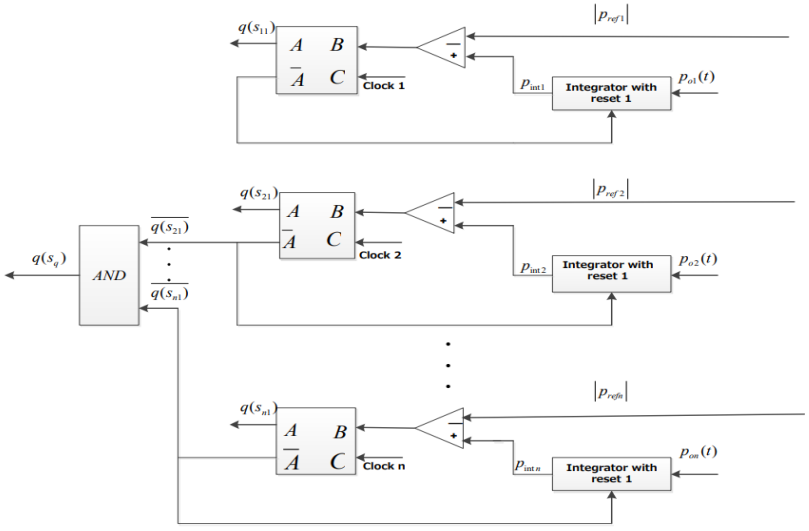

Figure 3. Control diagram of CPS OCC for the two-stage CSD inverter

3. SIMULATION AND RESULTS

Figure 4 displays the output voltage with five levels. As we know, there are five distinct voltage levels in the square waveform where the output voltage is located in this instance. Here the input DC voltage is 200V in magnitude. In Figure 4, the waveform starts from –100 V and increases up to a maximum of 200 V and starts decreasing from 200 V to –200 V in 5 steps so it is called a five-level inverter. In Figure 4 time is indicated on the X-axis, and the output voltage is represented on the Y-axis. Within Figure 5 The time in seconds is shown by the X-axis, and the PWM input to each thyristor is indicated by Figures 5(a)-(f) the Y-axis. The output waveforms of the active switches after the applications of the PWM technique and we can observe that the magnitude and width of every waveform are different.

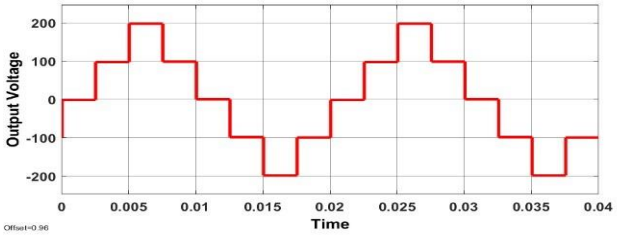

Figure 4. The five-level output waveform of the proposed two-stage CSD

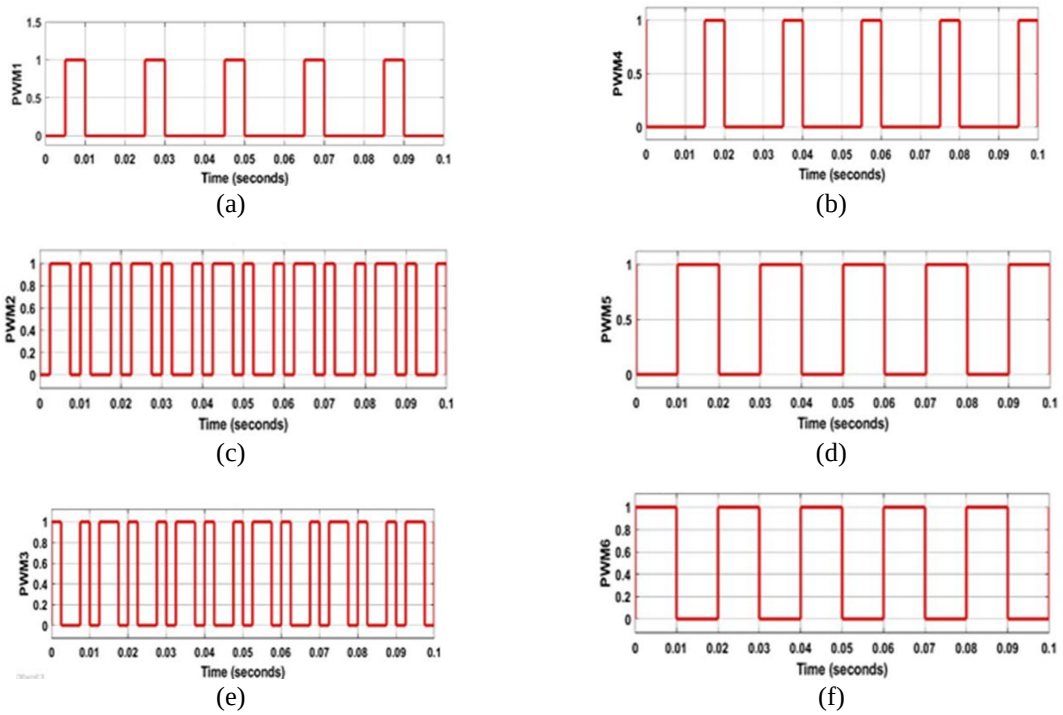

Figure 5. Output waveforms of active switches after the application of the PWM technique in (a) PWM1, (b) PWM2, (c) PWM3, (d) PWM4, (e) PWM5, and (f) PWM6

4. CONCLUSION

A novel cascaded switched diode five-level inverter produces higher voltage levels and also improves the waveform quality compared to the other two-level inverters. This higher voltage allows the more efficient and reliable energy conversion, reducing power losses and increasing overall system performance. Also, the ability to switch between different voltage levels with a minimum number of switching losses to ensure smooth operation and better performance, mainly in different environmental conditions. Two-stage cascaded switched diode five-level inverter mainly aims to generate an efficient output voltage and it is very suitable for medium voltage renewable energy applications. The full bridge inverter is added as the second stage converter for both positive and negative output voltage levels, and this results in the removal of high voltage spikes caused by the collapsing magnetic field in short time intervals. Additionally, the spike removal switch added in the first stage provides the path for the reverse load current R-L loads. These benefits include reduced component count, lower cost, and improved performance by sending voltage spikes.

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