Phase Shift Modulation for Cascaded H-Bridge Multilevel Converters for Voltage Regulation

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***Abstract*: This paper presents a new Cascaded H-bridge multilevel power electronic converters generally need some dc sources. An another option is to replace all the separate dc sources of the H-bridge cells with capacitors, exit only one H-bridge cell with dc voltage source. This converter output is a cost-effective. The capacitor is used to balancing the voltage in converter. In this paper, the phase-shift modulation technique is used as a new control method for cascaded H-bridge multilevel converters fed with only two independent dc source is presented. The proposed method has a wide voltage regulation range for the replacement capacitors in the H-bridge cells. Simulation results support the proposed control method.**

***Keywords*: H-Bridge, Ultracapacitors, Multilevel Converter.**

I. INTRODUCTION

In Multilevel power electronic converters, the coveted yield voltage is incorporated by joining a few isolated dc voltage sources [1]–[3]. Sunlight based boards, power modules, batteries, what's more, ultracapacitors are the most widely recognized autonomous sources utilized [4][5]. These converters have single-and three-stage applications. The principle points of interest of multilevel converters are low symphonious mutilation of the created yield voltage, low electromagnetic emanations, high proficiency, the capacity to work at high voltages, and measured quality [4], [6]– [8]. All in all, multilevel converters are arranged into diode-clasped [9]– [11], flying capacitor [12]– [14], and cascaded H-bridge multilevel topologies [1][15]. Utilizations of diode clamped multilevel converters incorporate high-control air conditioning engine drives in transports, pumps, fans, and plants [3], [4],

[15]. The flying capacitor multilevel converter has been utilized as a part of high-data transfer capacity high-exchanging frequency applications, for example, medium-voltage footing drives [6]. At long last, the cascaded H-bridge multilevel converter has been bridged to high-power and astounding applications [1], for example, static volt-ampere receptive generation [1], dynamic filters, reactive power compensators, photovoltaic power change [5], [8] uninterruptible power supplies, and attractive reverberation imaging. Moreover, one of the developing applications for multilevel power electronic converters is electric-drive vehicles in which the footing engine is driven by batteries [15]. The technique used to switch cascaded H-bridge cells can be construct either in light of the essential exchanging frequency, i.e., staircase adjustment, or the pulse width modulation (PWM) procedure [7]. In the essential exchanging frequency approach, the exchanging misfortunes are less, however the music in the yield voltage waveform show up at lower frequencies.

A few techniques are proposed in the writing to specifically dispense with music in the yield waveforms of multilevel converters [7]. In the PWM exchanging technique, the music in the yield waveform show up at higher frequencies, however because of a higher exchanging frequency, the exchanging misfortunes are more prominent [7]. Fig1 demonstrates the piece graph of a cascaded H-bridge inverter framework, which comprises of primary and assistant H-bridge cells. In early executions[2], every H-bridge cell was provided by an autonomous dc source. Afterward, look into appeared that just a single cell should be provided by a dc control source; the rest of the cells can be sustained by capacitors [7], [11]. The technique proposed in [7], employments the exchanging state repetition for capacitor voltage direction, where the voltage level of the assistant cell more often than not is chosen to be a large portion of that of the fundamental H-bridge cell. Be that as it may, ponders have demonstrated that managing the capacitor voltage is not as simple as at first anticipated [7] .The presence of excess exchanging states has been thought to be sufficient for capacitor voltage control. Be that as it may, the yield current of the inverter also, the time term of the repetitive exchanging states extraordinarily affect the charging or releasing examples of the substitution capacitors [7]. This paper proposes a control strategy pertinent to single dc-source cascaded H-bridge multilevel inverters to progress their capacitor voltage control. The proposed technique, phase shift balance, is powerful and does not cause much computational trouble. In this technique, the primary inverter switches at the central frequency, and the assistant inverter switches at the PWM frequency.

II. MULTILEVEL H-BRIDGE CONVERTER FUNDAMENTALS OF OPERATION

The structures of the principle and auxiliary cells are fundamentally the same as each other, the main distinction being that the primary inverter utilizes a dc voltage source or a battery while the assistant inverter utilizes a capacitor (see Fig. 1). H-bridge cells are associated in arrangement; consequently, the orchestrated voltage waveform is the entirety of all individual Where α is

the conduction angle of the primary H-bridge cell yields. The yield voltage of the inverter can be portrayed as (see Fig. 2). The rest of the piece of the yield voltage, i.e., the base follow in Fig. 2, should be blended by the helper H-bridge cell. This coveted voltage can be portrayed as

$$v_{\text{out}} = v_1 + v_2. \qquad (1)$$

In most applications, the desired output voltage waveform of the cascaded H-bridge multilevel inverter is a sinusoidal waveform that can be described as

$$v_{\text{out,ref}}(t) = V_m \sin(\omega t) \qquad (2)$$

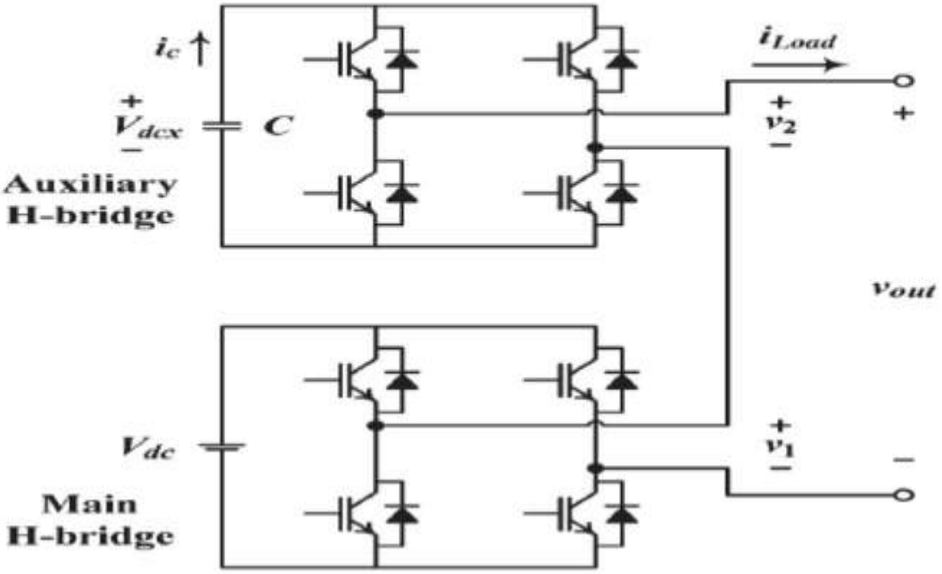
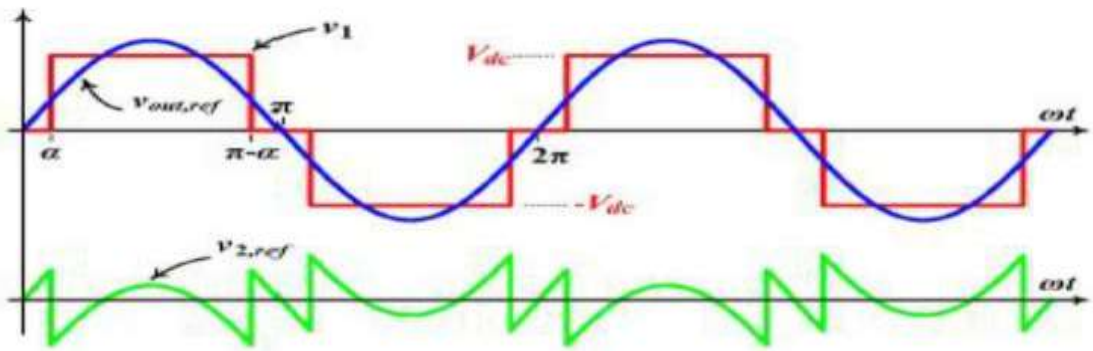


Fig 1. Block diagram of a cascaded H-bridge inverter.

Where Vm is the coveted amplitude of the yield voltage. Fig. 2 depicts how the desirable yield voltage waveform is blended utilizing the primary and helper H-bridge cells. The primary H-bridge cell, which is provided by Vdc, creates a rectangular waveform (v1), the frequency of which parallels that of the coveted yield voltage. Moreover, the width of this rectangular waveform is picked such that the abundancy of its basic consonant additionally breaks even with that of the desirable yield voltage. At the end of the day

$$\alpha = \cos^{-1}\left(\frac{\pi V_m}{4V_{dc}}\right) \qquad (3)$$



$$v_{2,\text{ref}}(t) = v_{\text{out,ref}}(t) - v_1(t). \qquad (4)$$

The PWM technique at a higher frequency will be applied to the auxiliary cell to construct v2,ref (t). The conventional unipolar PWM switching method is used in this work.

III. PHASE-SHIFT MODULATION

Controlling the capacitor voltage in the assistant H-bridge cell is a testing task. In the technique proposed here, capacitor voltage control is accomplished by altering the dynamic power that the principle H-bridge cell infuses into the framework. By moving the voltage waveform created by the fundamental H-bridge cell (see Fig. 3) to one side or right, one can infuse progressively (or less) dynamic power, which can be utilized to charge (or release) the capacitor on the assistant cell. Some sensible suspicions are made to streamline the logical portrayal of the guideline of operation of phaseshift balance. Here, it is accepted that the yield voltage of the helper cell is equivalent to the told waveform for that cell, i.e., v2(t) = v2,ref (t). Since PWM switching is utilized for this H-bridge cell, this presumption is generally exact. The other presumption is that the yield current is sinusoidal, as the heap more often than not carries on like a low-pass filter. The Fourier arrangement of the rectangular yield voltage waveform of the primary cell can be communicated as

$$v_1(t) = V_m \sin(\omega t) + \sum_{n=3,5,\ldots} [a_n \sin(n\omega t) + b_n \cos(n\omega t)]$$
$$= V_m \sin(\omega t) + h_n(n\omega t) \qquad (5)$$

Where hn(nωt) envelops the greater part of the music in the yield of the primary cell with the exception of the central consonant. In light of (3), the greatness of the basic consonant of the primary cell's voltage is set to be equivalent to the extent of the yield voltage. Thus, the yield voltage of the helper cell is given by

$$v_2(t) = -h_n(n\omega t). \qquad (6)$$

For a general case, as shown in Fig. 3(a), in which the output current has a θ phase shift from the output voltage, i.e.,

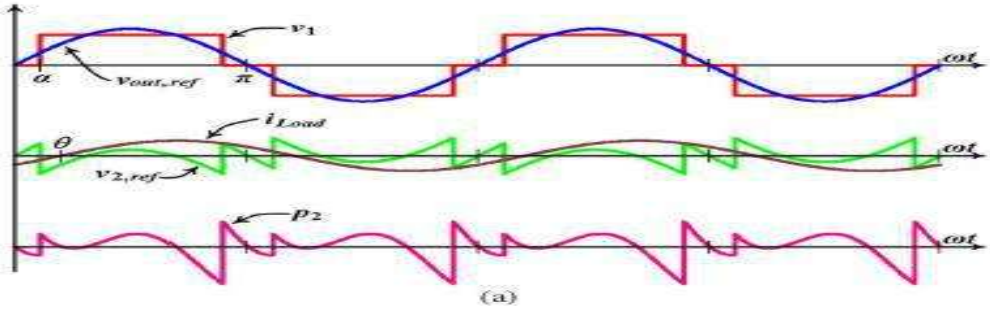
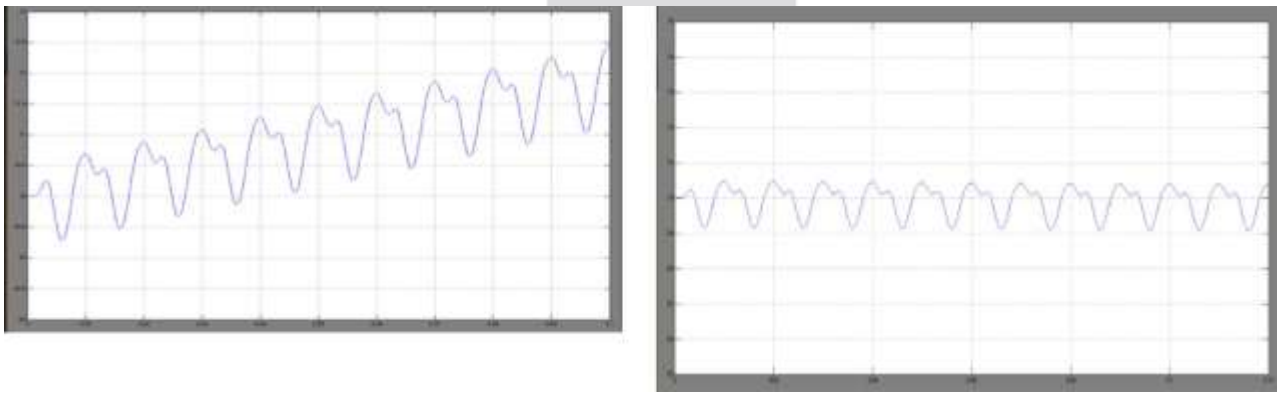
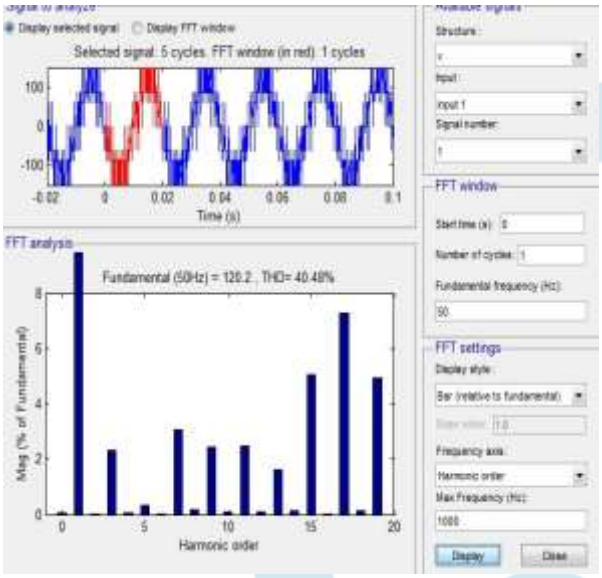


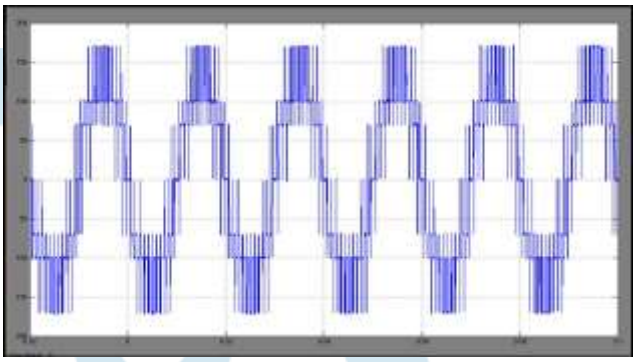
Fig 2. Desired output voltage waveforms of the main and auxiliary cells



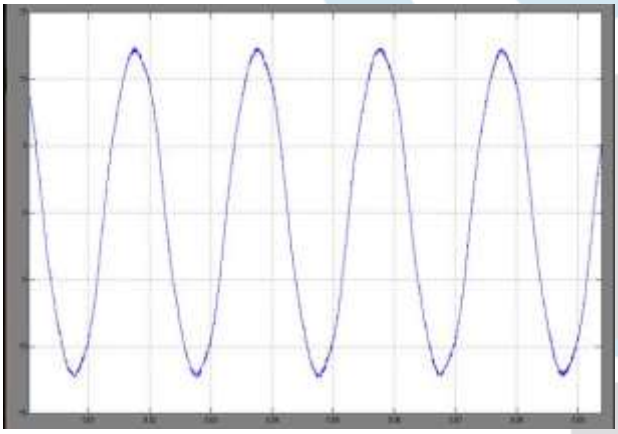
The simulation results of closed loop phase shift PWM has shown in bellow. Δα is adjusted to regulate the capacitor voltage in auxiliary cells. Simulation results of the closed loop phase-shift system, with an induction resistive as load, are depicted in Fig. 8 . From Fig. 8, it can be observed that Δα is very small, so it will not generate drastic harmonic distortions. Based on the results,

Fig8. Simulation results of the closed-loop phase-shift modulation.





(a). Inverter output voltage



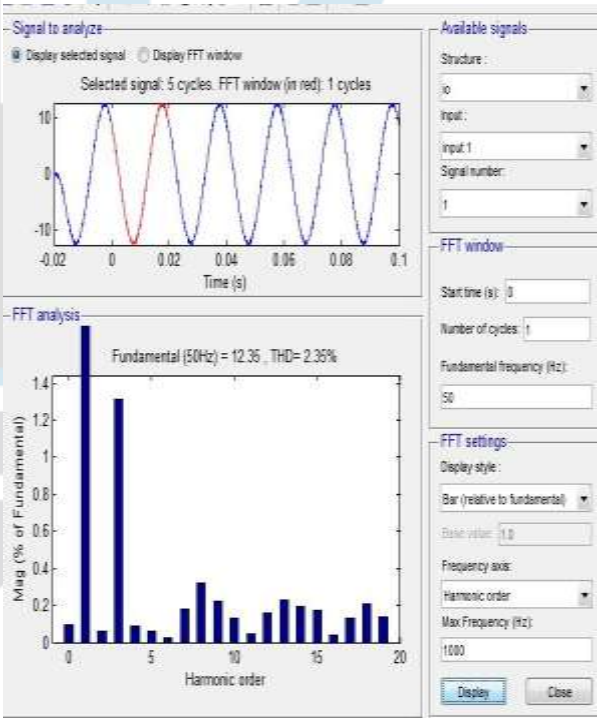
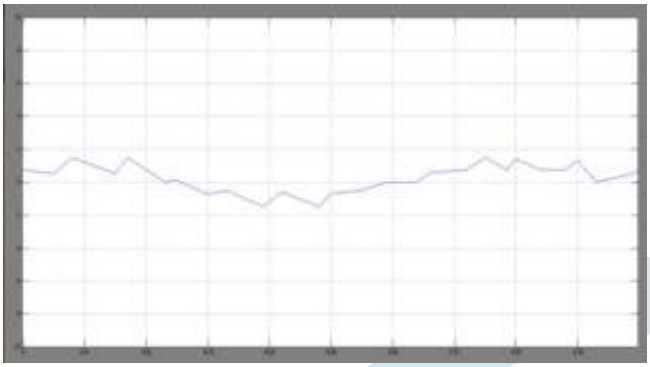


Fig9. THD waveform of load voltage

(b). Inverter output current



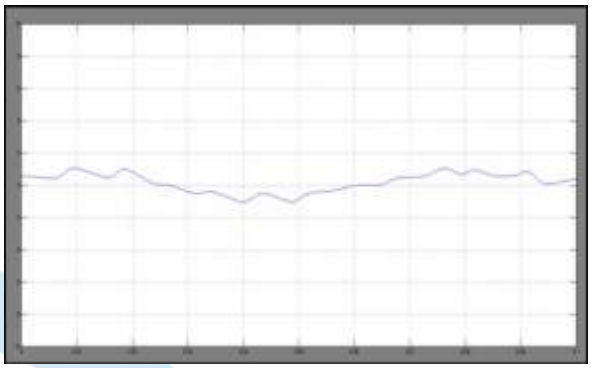
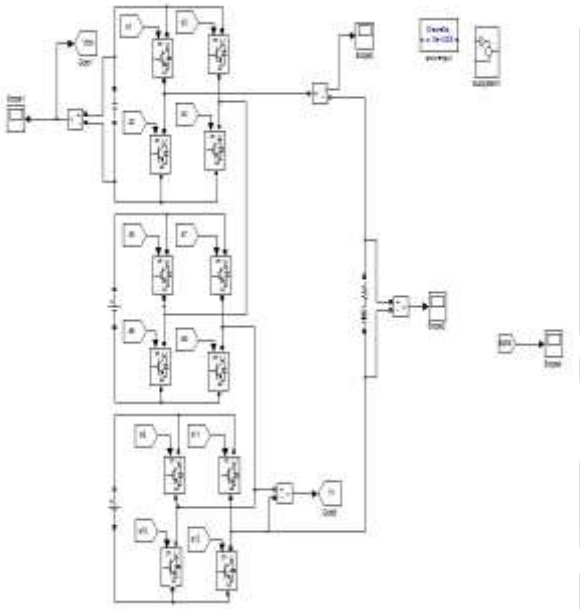


Fig10. THD waveform of load current.

B. Extension

The structures of the principle and auxiliary cells are fundamentally the same as each other, the main distinction being that the primary inverter utilizes a dc voltage source or a battery while the assistant inverter utilizes a capacitor (see Fig. 9).two cascaded H-bridge cells are associated in arrangement; consequently, the orchestrated voltage waveform is the entirety of all individual cell yields. The simulation block diagram of one auxiliary cell and two H-bridge cells are shown bellow.



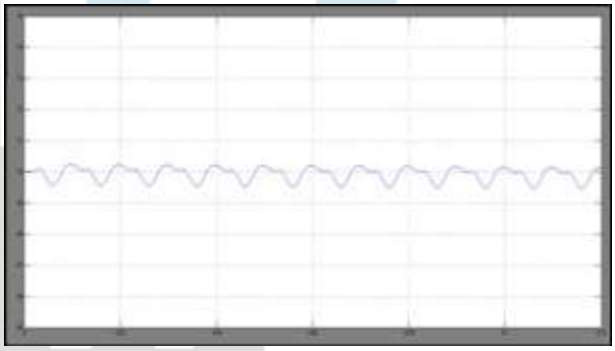
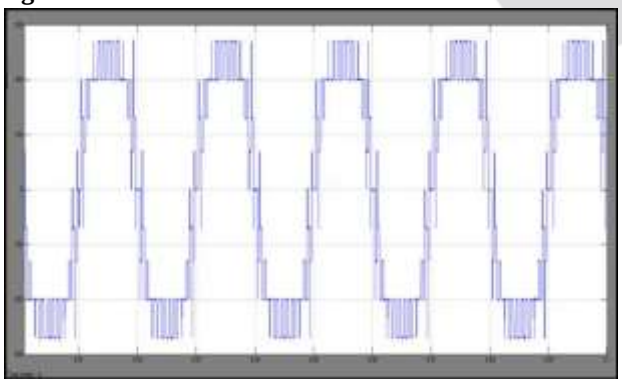


Fig15. Capacitor voltage

Fig11. Simulink Model.



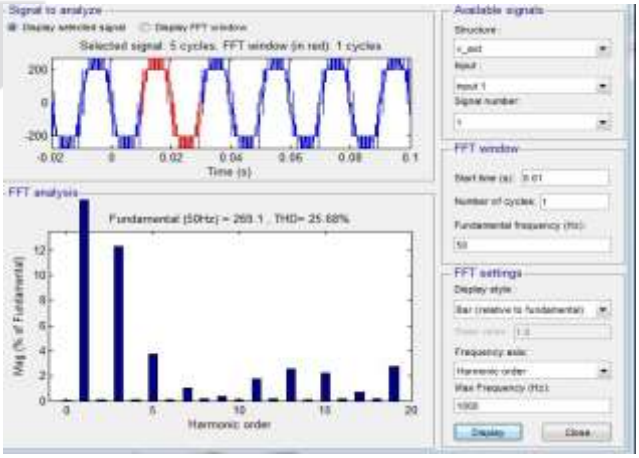
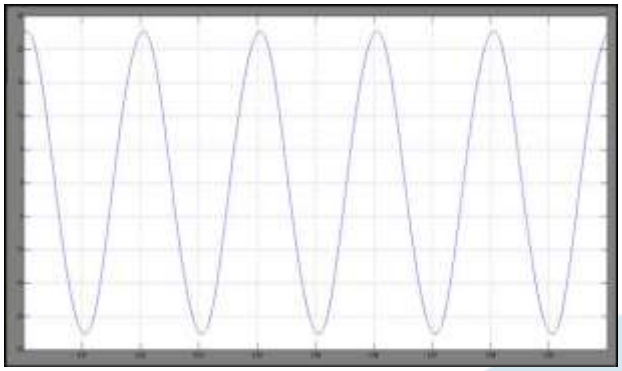


Fig15. Thd waveform of load voltage



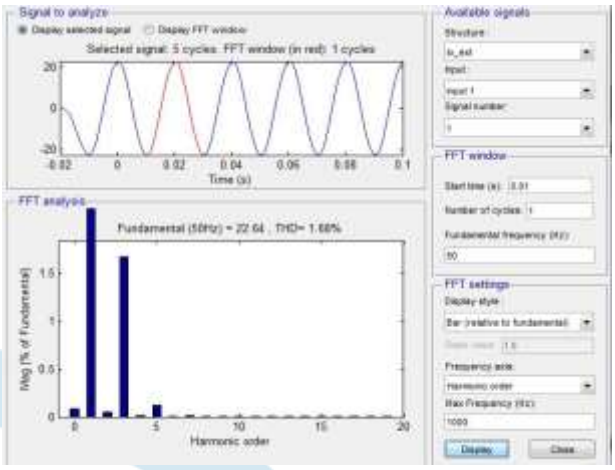


Fig16. Thd waveform of load current

Table1. Comparison table

	Proposed (7level)	Extension (9level)
Load voltage	40.48%	25.68%
Load current	2.35%	1.68%

VI. CONCLUSION

A new control method, phase-shift modulation, is used to achieve voltage regulation for the capacitors replacing the independent dc sources in the auxiliary H-bridge cells. The main H-bridge cells switches at the fundamental frequency while the auxiliary inverter switches at the PWM frequency. The proposed approach has less computational burden and has more robust capacitor voltage control. The simulation results agree with the analysis and show that the regulation of the capacitor voltage is achievable without deteriorating the total harmonic distortion.

VII. REFERENCES

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