IMPLEMENTATION AND CONTROL DIFFERENT MULTILEVEL INVERTER TOPOLOGIES FOR CURRENT WAVEFORM IMPROVEMENT

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ABSTRACT
Multilevel converters offer advantages in terms of the output waveform quality due to the increased number of levels used in the output voltage modulation. This advantage is particularly true for cascade H-bridge (CHB) converters that can be built to produce a large number of levels owing to their modular structure. In this paper, the NPC connected with the H-bridges (HBs) is used for improving the voltage waveform quality. Further more, NPC converter can be replaced with flying capacitors to get an improved output current waveform. This topology requires only a main dc-link voltage and presents a easy way to increase the output voltage levels by increasing the number of cells. The experimental results show the good performance of the proposed modulation technique and the resulting improvement in the output current waveform are provided.

KEYWORDS: *Current control, harmonic distortion, power electronics*

I. INTRODUCTION

The multilevel topologies can be classified into three main categories: the neutral point clamped (NPC)[1], the flying capacitors[2], and the cascade H-bridge (CHB) converters. The three-level NPC bridge is probably the most widely used topology for medium-voltage ac motor drives and pulsewidth modulation (PWM) active rectifiers[3],[4].NPC converters with more levels are also possible, although there are significant problems in the balancing of their dc link capacitor voltages[5],unless modified modulation strategies or an additionally circuitry is used. In applications with no active power transfer, such as in reactive power compensation, where the converter can operate without the rectifier front end, the CHB is a highly attractive Solution.

In recent years, an increased interest has been given to hybrid topologies integrating more than one topology in a single converter. In this topology, the NPC is used to supply the active power while the H-bridges (HBs) operate as series active filters, improving the voltage waveform quality by only handling the reactive power. In this way, this topology reduces the need for bulky and expensive LCL passive filters, making it an attractive alternative for large power applications [6],[7].

In this paper, the control strategy for the FLYING CAPACITOR- HB s hybrid converter, previously introduced is experimentally verified which improves the quality of the output current waveform.

II. HYBRID POWER CIRCUIT

2.1 Power circuit

The 3-phase, 3-level NPC multilevel inverter consists of twelve IGBTs, six clamping diodes and two capacitors. The clamping diodes are connected in such a way that it blocks the reverse voltage of the capacitor. Two capacitors have been used to divide the DC link voltage into three voltage level i.e. +Vdc, 0V and –Vdc, thus the name of 3-level.In this work, twelve triggering signals are needed for

the 3-level NPC inverter. These signals should be synchronized with the AC supply voltage. With this NPC circuit the H-BRIDGE was connected.
The considered hybrid topology is composed by a traditional three-phase three-level NPC inverter, connected with a single phase HB inverter in series with each output phase[6]-[8] .The power circuit is illustrated in Fig. 1, with only the HB of phase *a* shown in detail.

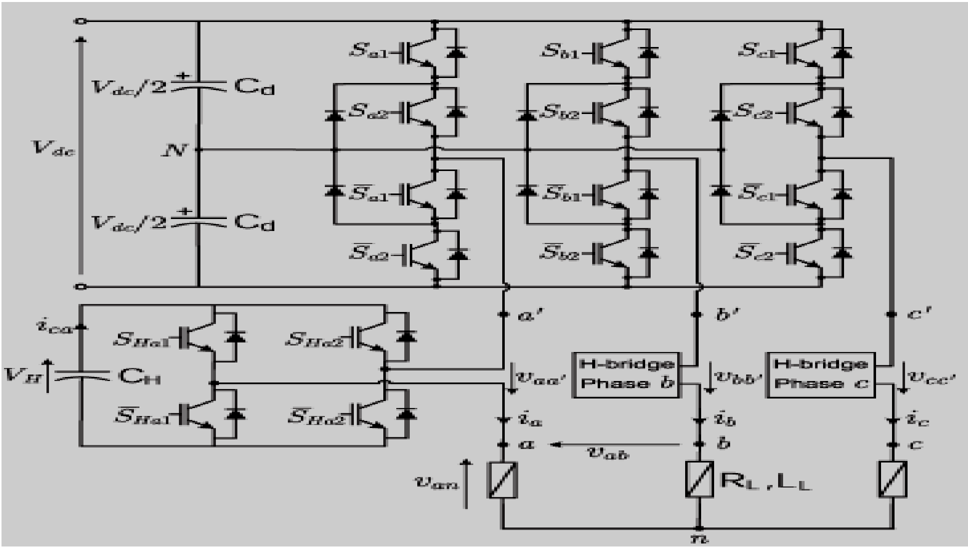

Fig. 1. Hybrid topology power circuit.

In the hybrid topology considered, the NPC inverter provides the total active power flow. For a high-power medium-voltage NPC, there are advantages to using latching devices, such as integrated gate-commutated thyristors (IGCTs), rather than insulated-gate bipolar transistors (IGBTs) due to their lower losses and higher voltage blocking capability[6],[8],[9], imposing a restriction on the switching frequency. In this paper, an NPC operating at a low switching frequency (of 250 Hz) is considered. In contrast, the HBs are rated at a lower voltage and need to be commutated at a higher frequency for an effective active filtering effect. This calls for the use of the IGBT.
The proposed converter, shown in Fig. 1, can be analysed from two different points of view. The first interpretation is as a single hybrid multilevel inverter with a nine-level phase voltage, achieved by the cascade connection of a three-level NPC leg and an HB per phase. The second interpretation is as an NPC converter with a series active filter that compensates for the harmonic content introduced by the low switching NPC stage.
For the modulation of the NPC inverter, the selective harmonic elimination (SHE) method has been selected. This method has the advantage of very low switching frequency and, hence, low switching losses while eliminating the low order harmonics.

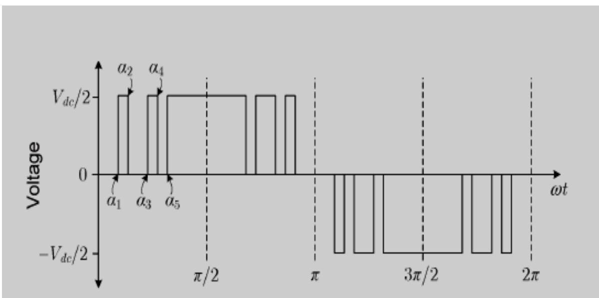

Fig.2. Three-level NPC-SHE phase voltage waveform.

2.2 NPC SHE

A qualitative phase output voltage waveform is presented in Fig. 2 considering a five-angle realization, so five degrees of freedom are available. This enables the amplitude of the fundamental component to be controlled and four harmonics to be eliminated. Since a three-phase system is considered, the triple harmonics are eliminated at the load by connection, and hence, they do not require elimination by the modulation pulse pattern.

Thus, the 5th, 7th, 11th, and 13th harmonics are chosen for the elimination. For variable frequency drive applications, the number of angles must be varied in order to maintain a near constant switching frequency at any operation point [10].

III. CONTROL STRATEGY

3.1 HB CONTROLLER

Each series HB converter is independently controlled by two complementary references, as shown in Fig. 3 .The first reference : $v^{+}_{aa'}(f_n)$ corresponds to the inverse of the harmonics remaining from the SHE pulse pattern, calculated as described in the previous section from the difference between the NPC pulsed voltage pattern and its sinusoidal voltage reference. This calculation provides a fast and straightforward distortion estimation allowing for simple feed-forward compensation. Moreover, this voltage does not have a fundamental voltage component, and hence, it does not affect the floating average dc-link capacitor voltage. Nevertheless, to achieve a start-up capacitor charge and to compensate the voltage drift due to transient operation, an additional reference component for dclink voltage control is included. This second component of the voltage reference *vaa'* (*f*1) corresponds to a signal in phase with the load current.

During operation, the fundamental load current is generated by the NPC converter. In order to synchronize the voltage reference *vaa'* (*f*1) with this current, a phase lock loop (PLL) algorithm is used, which guarantees a zero phase shift between both signals and therefore maximizes the active power transfer to the capacitors for any power factor. The magnitude of this voltage reference is obtained from the dc-link voltage controller shown in Fig. 3.

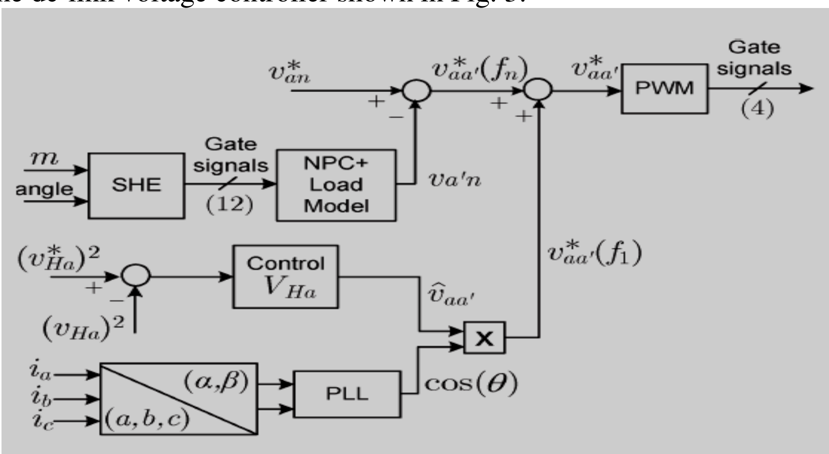

Fig. 3 . HB control diagram for phase *a*.

For the design of this voltage controller, the dynamic model(1) of the dc-link voltage *vHa* as a function of ˆ*vaa_* is used.

$$\frac{C_H}{2} \cdot \frac{dv^2_{Ha}}{dt} \approx \frac{\hat{i}_a \cdot \hat{v}_{aa'}}{2}. \tag{1}$$

An undesirable characteristic of (1) is its nonlinearity with respect to *vHa*. This can be dealt with by linearization or by simply introducing the auxiliary variable *x* = *v*^2*Ha* and controlling *x* directly.

IV. SIMULATION DIAGRAM OF NPC WITH H-BRIDGE INVERTER

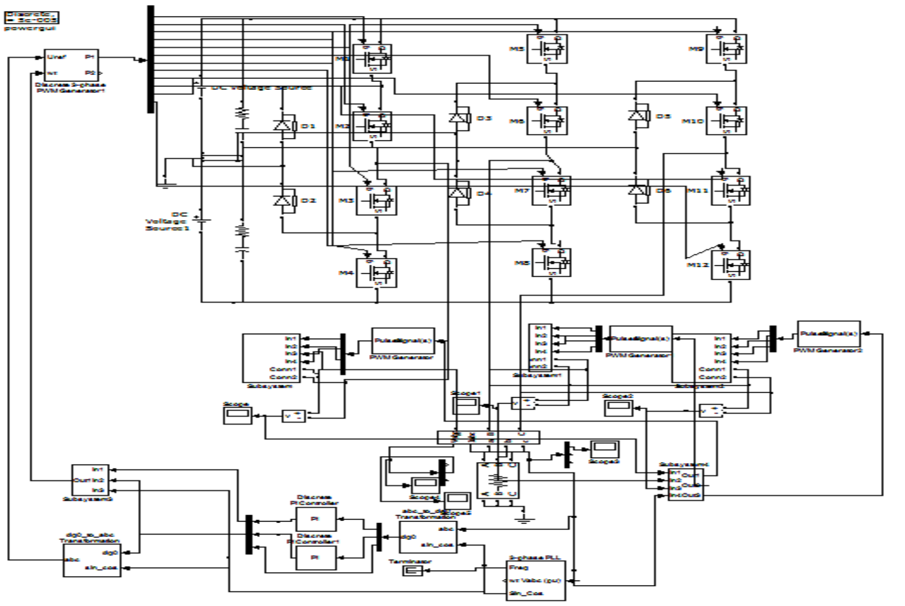

Fig 4. Simulation diagram of NPC with H-BRIDGE inverter.

V. SIMULATION RESULTS OF NPC WITH H-BRIDGE INVERTER

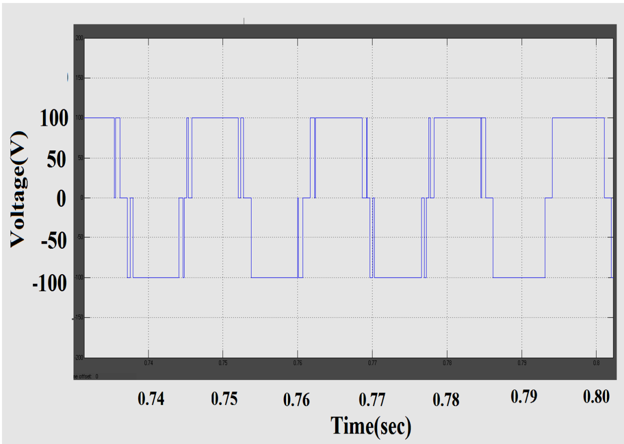

Fig 4.a Observed output waveform-NPC

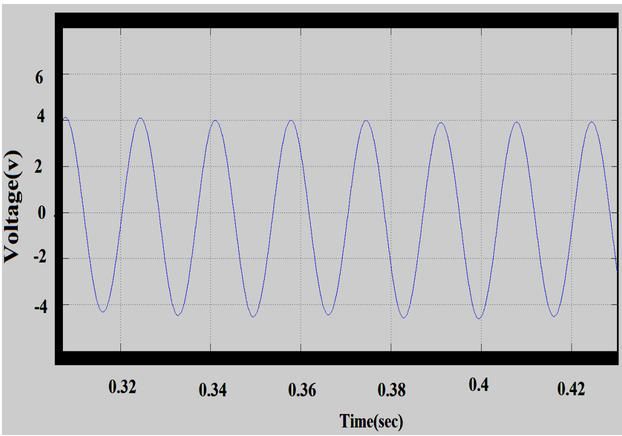

Fig 4.b. load voltage waveform

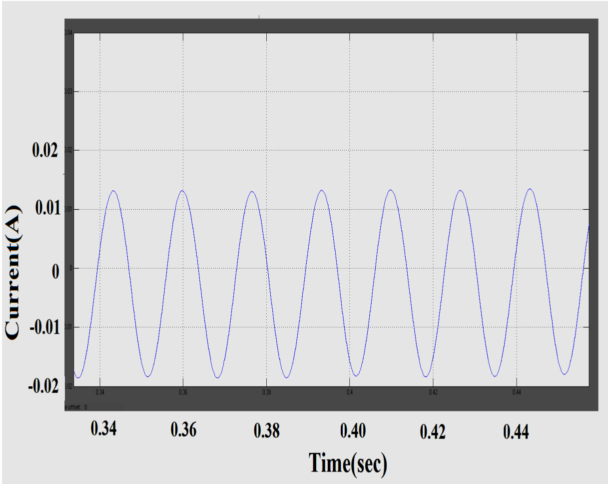

Fig 4.c.load current waveform

VI. THD ANALYSIS OF NPC AND H-BRIDGE

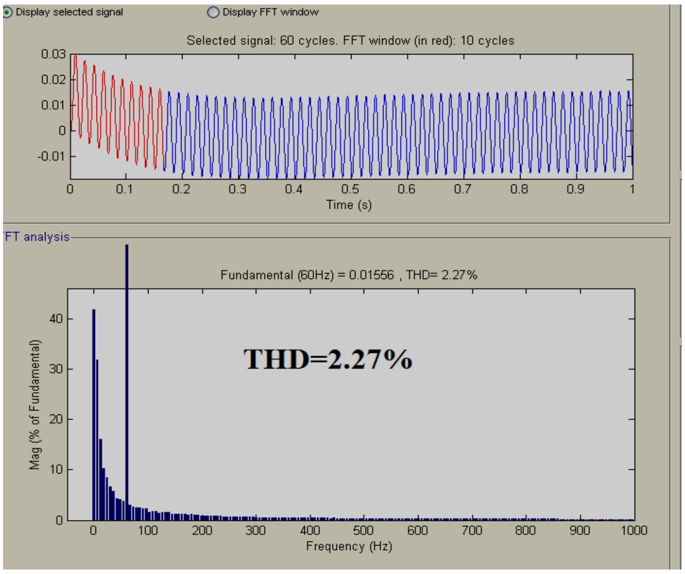

Fig.5. Harmonic analysis of NPC with H-BRIDGE

The operation of the hybrid converter shows almost a complete elimination of these characteristic harmonics, resulting in a current THD of **2.27%.**

VII. IMPLEMENTATION OF ANOTHER TOPOLOGY WITH FLYING CAPACITORS

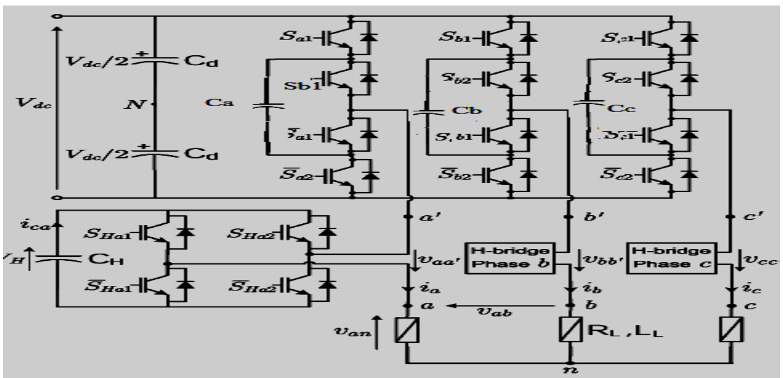

Fig .6. Power circuit with flying capacitors and H-bridge inverter

The operation of the above circuit is almost similar to the first topology. The capacitor connected across the switches charges when Sa1 is ON and Sa2 remains OFF. At this condition the output voltage is Vdc/2.Then the capacitor starts discharging when Sa1 turned OFF with the output voltage of –Vdc/2.

A. External current control loop

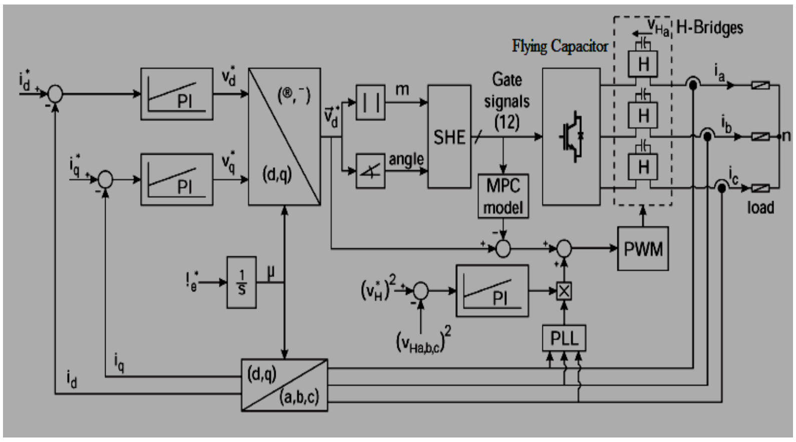

Fig. 7. Simplified current control loop for the proposed topology, including SHE for the flying capacitor (the control loops for the HBs are not shown).

It is important to note that, in applications with low frequency switching patterns, such as the SHE modulation, the use of direct synchronous sampling of the currents is not adequate to obtain the fundamental current because the switching harmonics do not cross zero at regular intervals. Instead, the observers are needed to extract the fundamental current values; otherwise, complex nonlinear control schemes are required.
In this paper, this problem is overcome by the compensating effect of the series-connected HBs. This effectively simplifies the outer load current control loop design, resulting in a standard *dq* frame linear current regulator a. In a regenerative operation, such as active front end applications for regenerative drives, the power flow needs to be controlled bidirectionally.

VIII. SIMULATION DIAGRAM OF FLYING CAPACITOR WITH H-BRIDGE INVERTER

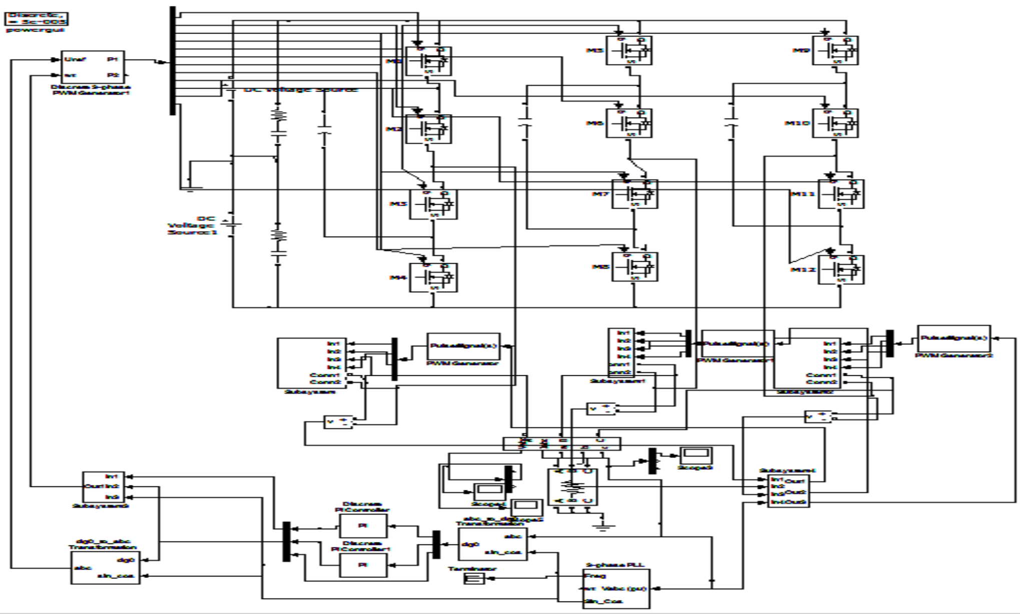

Fig 8. Simulation diagram of FLYING CAPACITOR with H-BRIDGE inverter.

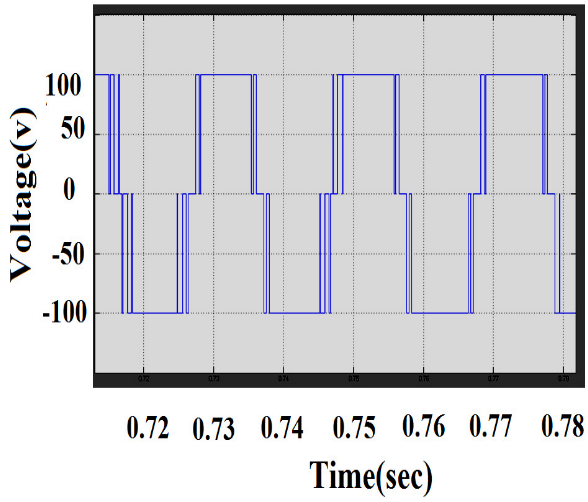

Fig.8.a Observed output waveform - flying capacitor

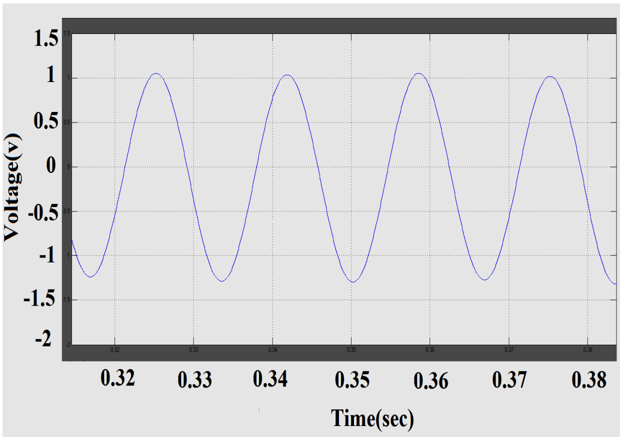

Fig.8.b. load voltage waveform

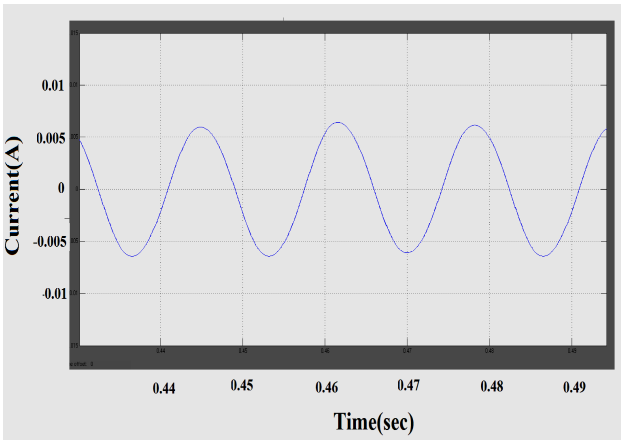

Fig 8.c.load current waveform

IX. THD ANALYSIS OF FLYING CAPACITOR AND H-BRIDGE

The operation of the Flying capacitor with H-Bridge converter shows almost a complete elimination of these characteristic harmonics, resulting in a current THD of **1.36%.**

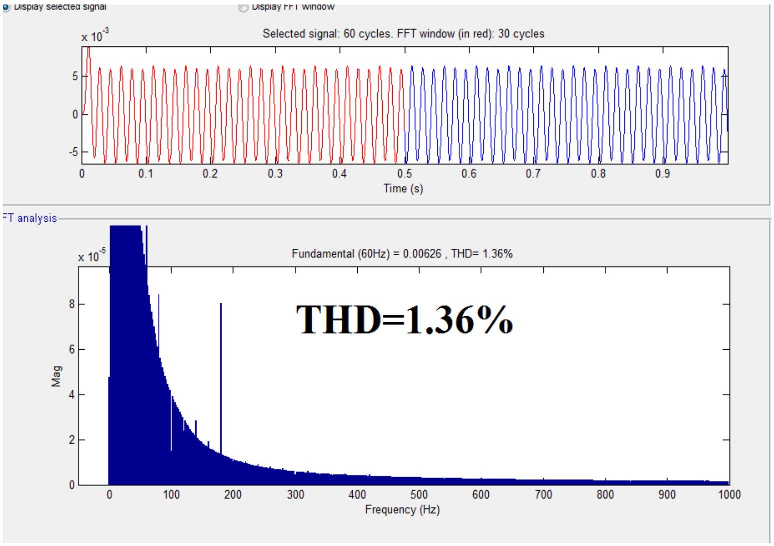

Fig 9. Harmonic analysis of FLYING CAPACITOR with H-BRIDGE

X. CONCLUSION

This paper has presented the series connection of a SHE modulated NPC and an HB multilevel inverter with a control scheme to control the floating voltage source of the HB stage. The addition of the HB series active filter or additional converter stage is not intended to increase the power rating of the overall converter. Rather, the main goal is to improve, in a controllable or active way, the power quality of the NPC Bridge which may have a relatively low switching frequency. And in the proposed topology the flying capacitor with H-Bridge converter was connected and the current waveform was improved and the THD was reduced to **1.36%.**

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