

# Harmonic Reduction of Enhanced Single Phase Step-Up Five-Level Inverter Using Lcl Filter

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## ABSTRACT

One of the important criteria is the quality and harmonic contents of the current being injected to the grid. High-order harmonics of the grid current should be very limited (lower than 0.3% of the fundamental current). Beside the topology of the power electronic interface, the output filter also affects the quality of the load voltage. Proposed a 5-level inverter is presented for grid integration systems along with its output LCL filter design. Analytical calculation of losses for the 5-level inverter and the output LCL filter is presented. It is also compared to the H-bridge inverter in terms of output voltage and current harmonics, and the overall losses.

## 1. INTRODUCTION

### 1.1 GENERAL

In the past decade, renewable energy sources such as photovoltaic (PV)-based systems have attracted much more attention due to the advantages such as less environmental impact and improved economic benefits. With the rapid growth of power electronics technology, various converters topologies have been developed for PV systems. Among these topologies, multilevel inverters have been receiving significant interest due to the reduced total harmonic distortion (THD) and improved quality of output waveform. As the output voltage level increases, the output harmonic content of such inverters decreases, allowing the use of smaller output filters. For single-phase multilevel inverters, the most common topologies are the neutral-point-clamped (NPC).

### 1.2 SCOPE OF THE PROJECT

The scope of the project is used to enhance the stepped up five level inverter.

## II. MULTI LEVEL INVERTERS

An inverter is an electrical device that converts direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. Static inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that

transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters were made to work in reverse, and thus were "inverted", to convert DC to AC.

### 2.1 Cascaded H-Bridges inverter

A single-phase structure of an m-level cascaded inverter is illustrated in Figure 4.1. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs,  $+V_{dc}$ , 0, and  $-V_{dc}$  by connecting the dc source to the ac output by different combinations of the four switches,  $S_1$ ,  $S_2$ ,  $S_3$ , and  $S_4$ . To obtain  $+V_{dc}$ , switches  $S_1$  and  $S_4$  are turned on, whereas  $-V_{dc}$  can be obtained by turning on switches  $S_2$  and  $S_3$ . By turning on  $S_1$  and  $S_2$  or  $S_3$  and  $S_4$ , the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in a cascade inverter is defined by  $m = 2s+1$ , where s is the number of separate dc sources. An example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 4.2. The phase voltage

$$V_{an} = V_{a1} + V_{a2} + V_{a3} + V_{a4} + V_{a5}$$

For a stepped waveform such as the one depicted in Figure 4.2 with s steps, the Fourier Transform for this waveform follows

$$V(\omega t) = \frac{4V_{dc}}{\pi} \sum_n [\cos(n\theta_1) + \cos(n\theta_2) + \dots + \cos(n\theta_s)] \frac{\sin(n\omega t)}{n}, \text{ where } n = 1,3,5,7 \dots$$

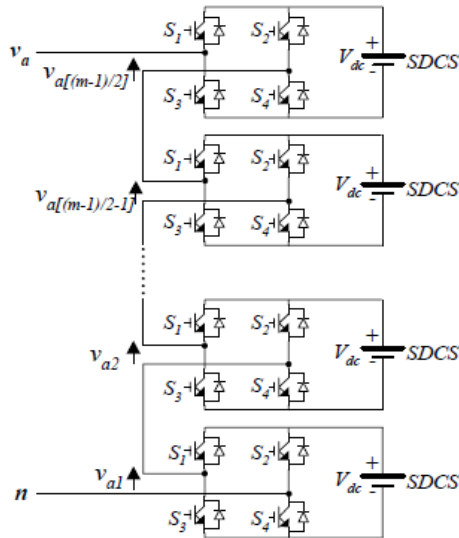


Fig.1 Single-phase structure of a multilevel cascaded H-bridges inverter

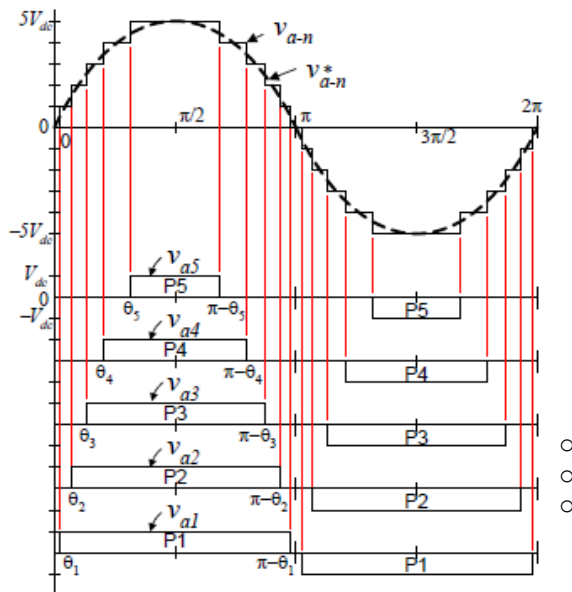


Fig.2 Output phase voltage waveform of an 11-level cascade inverter with 5 separate dc sources.

### III. PROJECT DESCRIPTION

#### 3.1 GENERAL

Overall, the abovementioned multilevel topologies only can realize the voltage step-down inversion, i.e., the ac voltage amplitude cannot exceed the input dc voltage. A “transformerless” architecture is competent since it reduces the system cost and

weight and realizes the voltage step up. However, two dc sources and corresponding split of dc bus capacitors are required as well as more switches and diodes in. The step-up ratio of the boost converter has some limitations which restrict the step-up capability. A high stepup inverter is proposed in using the diode-capacitor cell and couple inductor.

#### 3.2 MODULES NAME

- multilevel inverter,
- single phase

#### 3.3 MODULE DESCRIPTION

- multilevel inverter

Now a day’s many industrial applications have begun to require high power. Some appliances in the industries however require medium or low power for their operation. Using a high power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Some medium voltage motor drives and utility applications require medium voltage. The multi level inverter has been introduced since 1975 as alternative in high power and medium voltage situations. The Multi level inverter is like an inverter and it is used for industrial applications as alternative in high power and medium voltage situations.

The need of multilevel converter is to give a high output power from medium voltage source. Sources like batteries, super capacitors, solar panel are medium voltage sources. The multi level inverter consists of several switches. In the multi level inverter the arrangement switches’ angles are very important.

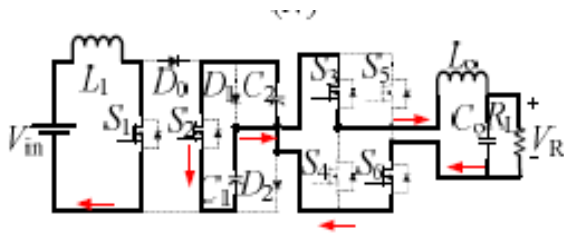
**Multilevel inverters are three types.**

- Diode clamped multilevel inverter
- Flying capacitors multilevel inverter
- Cascaded H- bridge multilevel inverter

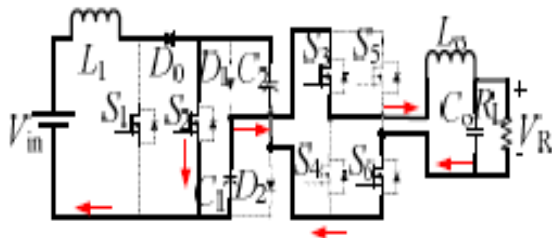
- single phase

**single-phase electric power** is the distribution of alternating current electric power using a system in which all the voltages of the supply vary in unison. Single-phase distribution is used when loads are mostly lighting and heating, with few large electric motors. A single-phase supply connected to an alternating current electric motor does not produce a revolving magnetic field; single-phase motors need additional circuits for starting, and such motors are uncommon above 10 kW in rating.





**Mode 6:** S2 stays ON state and S1 is turned OFF in this mode. Similar as mode 5, the capacitors C1, C2 are connected in series supplying power to the ac load. Similarly, there are six working modes when the inverter outputs negative voltage

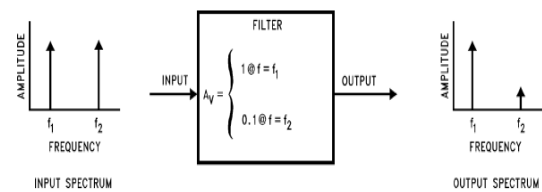


### 3.6 Filters

Filters of some sort are essential to the operation of most electronic circuits. It is therefore in the interest of anyone involved in electronic circuit design to have the ability to develop filter circuits capable of meeting a given set of specifications. Unfortunately, many in the electronics field are uncomfortable with the subject, whether due to a lack of familiarity with it, or a reluctance to grapple with the mathematics involved in a complex filter design.

In circuit theory, a filter is an electrical network that alters the amplitude and/or phase characteristics of a signal with respect to frequency. Ideally, a filter will not add new frequencies to the input signal, nor will it change the component frequencies of that signal, but it will change the relative amplitudes of the various frequency components and/or their phase relationships. Filters are often used in electronic systems to emphasize signals in certain frequency ranges and reject signals in other frequency ranges. Such a filter has a gain which is dependent on signal frequency. As an example, consider a situation where a useful signal at frequency  $f_1$  has been contaminated with an unwanted signal at  $f_2$ . If the contaminated signal is passed through a circuit (Figure 1.4) that has very low gain at  $f_2$  compared to  $f_1$ , the undesired signal can be removed, and the useful signal will remain. Note that in the case of this simple example, we are not concerned with the gain of the filter at any frequency other than  $f_1$  and  $f_2$ . As long as  $f_2$  is sufficiently attenuated relative to  $f_1$ , the performance of this filter will be satisfactory. In

general, however, a filter's gain may be specified at several different frequencies, or over a band of frequencies. Since filters are defined by their frequency-domain effects on signals, it makes sense that the most useful analytical and graphical descriptions of filters also fall into the frequency domain. Thus, curves of gain vs frequency and phase vs frequency are commonly used to illustrate filter characteristics, and the most widely-used mathematical tools are based in the frequency domain.



**FIGURE 3:** Using a Filter to Reduce the Effect of an Undesired Signal at Frequency  $f_2$ , while Retaining Desired Signal at Frequency  $f_1$ .

### IV. TYPES OF FILTERS

The power system must be free from harmonics and which will lead to numbers of benefits. A clean network has less strain on appliances and their lifespan are lengthened. Maintenance and replacement costs are lowered. So we go for filters. Filters can be classified into three types:

1. Active filter
2. Passive filter
3. Hybrid filter

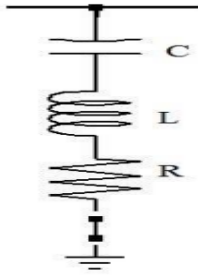
#### PASSIVE FILTERS

Passive harmonic filters consisting of capacitors, inductors, and resistors can be classified into

- (i) Tuned filters
- (ii) High pass filters.

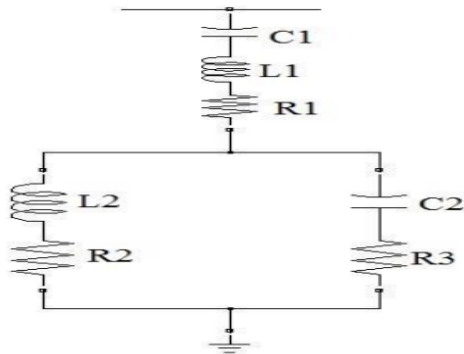
#### Tuned filters:

Tuned filters are used to filter out particular harmonic frequency.



**Fig 4 A single tuned filter.**

Fig. shows a Single tuned filter having series connection of a capacitor, an inductor, a resistor and separate out a single frequency harmonic.

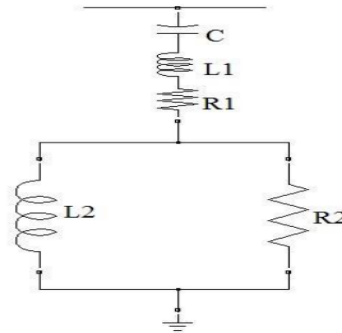


**Fig .5 Double tuned filter.**

A double tuned filter has characteristics of providing low impedance path to 2 harmonic frequencies. It has advantage of low loss at the lower frequencies. A double tuned filter is shown in fig.1.9.

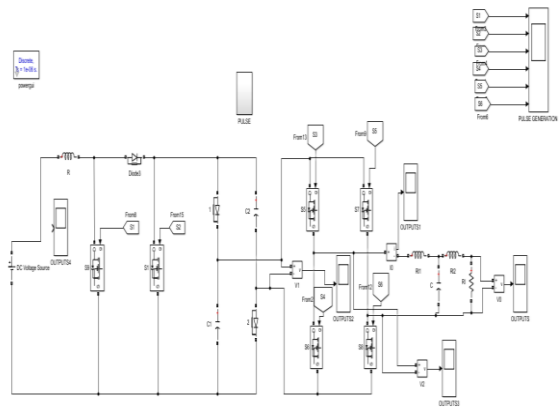
**High pass filter:**

The characteristic of high pass filters is to offer low impedance path to all the high frequencies.

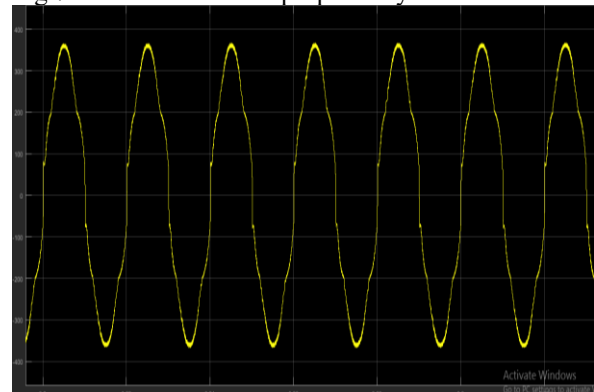


**Fig .6 High pass filter.**

**V. SIMULINK MODEL OF PROPOSED SYSTEM**



**Fig 7 Simulink model of proposed system**



**Fig8 load current**

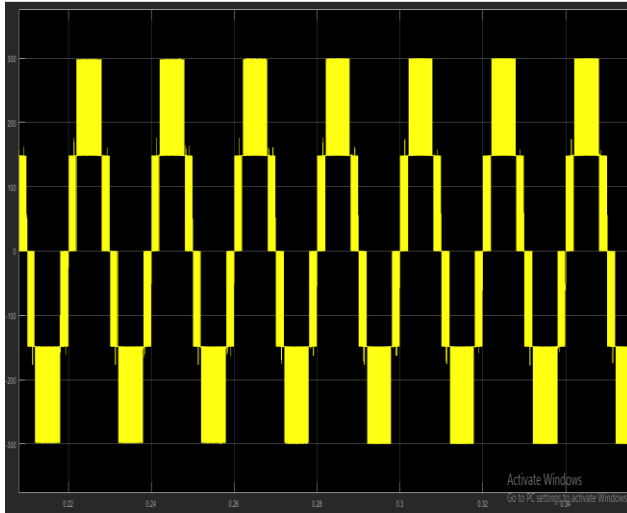


Fig9: Inverter output

## VI.CONCLUSION

The output LCL filter design as well as the harmonic analysis of the output voltage and current has been presented for the multilevel inverter. Also, the analytical efficiency analysis has been provided. The two inverters (multilevel and Hbridge) have been compared from different points of view such as losses and efficiency, output current ripple, and grid current THD and harmonics. As the results showed, the multilevel inverter has much lower harmonics and current ripple.

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