

Harmonic Investigation Analysis of Cascade H Bridge Multilevel Inverter with Conventional Inverter using PSIM

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Abstract: Multilevel inverters, such as flying capacitor, diode clamped, and cascaded H-bridge inverters, are widely used in medium and high-power applications. Complete harmonic distortion reduction and selective harmonic elimination have been suggested to achieve the goal of the research work and the reduction in unit count has also been taken into account. The filtering unit requirement is also minimized by the use of the transformer in the H Bridge Inverter cascade. A cascaded H-bridge module that generates an 11-level output voltage from a single direct current (DC) source is the subject of this research. The noble approach reduces the amount of switches and gate drivers compared to a standard strategy. The anticipated architecture produces more accurate results when using an isolation transformer and a high switching frequency. Although the multilevel inverter may utilize a number of modulation techniques, our research focuses on selective harmonic elimination modulation (SHE). This modulation approach reduces the number of carriers while also decreasing Switching Losses and Total Harmonic Distortion (THD), resulting in better Power Quality (PQ). Based on the simulation findings, SHE appears to be capable of removing selected harmonics by cutting off the fundamental output component. The PSIM simulation software and a THD analysis of both 5-level and 7-level multilevel inverters with and without transformers are used to evaluate the performance of the recommended cascaded multilevel inverter. The THD is calculated via an FFT analysis of the output voltage waveform of a multilayer inverter.

Keywords: Cascaded H-bridge Multilevel Inverter, Power Quality, Total Harmonic Distortion, Selective Harmonic Elimination.

I. Introduction

Multilevel inverters are power-conversion systems composed of an array of power semiconductor switches and voltage or current sources, when properly connected and controlled, can generate waveform with variable and controlled frequency, phase, and amplitude [1]. For the balance of current in the input and PC, the control technique utilizes the advantages of the SMC to obtain a good signal of grid current, as it distinguishes both functions. A variation of its original variant that does not involve knowledge of the system's mathematical model is the PC-based process. This value of the approach proposed can be particularly appealing, as it can be difficult to find the system model. Compared to the findings, the topology and the proposed strategy allow the reduction of the input inductors. The DC/AC converters transform the DC into AC, usually called inverters, and are known as Voltage Source Inverters (VSIs) or Current Source Inverters (CSIs). The Multilevel Current-Source Inverters are a version of the CSI (MCSIs). A new predictive control strategy for an MCSI with multiple inputs and connected to the grid is proposed in this paper. In order to achieve an effective grid current, the control technique uses the advantages of Sliding Mode Control (SMC) for the balance of current in the input and Predictive Control (PC) as it distinguishes both functions [4]. Recently, multi-level cascading transformers are proposed. These have the advantage that a single DC voltage source and a transformer for transformation and insulation of voltage can be used [2]. The cascade transformers' Leakage Reactance provides the harmonic components of inverter output voltage with a high efficiency filtering effect [3].

To convert the dc power into ac, a highly efficient converter is required for optimum utilization of energy. The MPPT algorithm uses the IPV and VPV of the PV array and gives the MPP and a VDCREF. This voltage is then passed on to the inverter and then further to the three-phase grid. In this thesis the behavior of the active and reactive power of the grid which is supplied by the PV array is investigated. The various currents such as inverter current, grid current and load currents are also investigated [5].

Inverters are the components that convert DC electricity to AC power at the specified output voltage. It also has other advantages, such as higher power quality, fewer order harmonics, lower switching losses, and lower electromagnetic interference and frequency. However, it has some disadvantages, such as large switching losses, expensive prices, and lower performance. Because of these drawbacks, multilevel inverters are preferred over regular inverters. The output of the multilevel inverter is a staircase waveform that is identical to the sinusoidal waveform. The quantity of harmonics present in the output voltage of a multilayer inverter is substantially lower than that of a normal two-level inverter. The harmonic distortion from the output voltage value decreases to zero as the multilayer inverter levels grow to N. The three types of multilevel inverters are multilevel cascaded inverter, inverter flying capacitor, and inverter clamped diode [6]–[8].

Traditional method to determine the switching angles with less complexity are proposed in [9]. The switching angles that would provide the lowest total harmonic distortion (THD) and power quality (PQ) in the voltage output waveform are selected for inverter switching once the switching pattern is established as necessary [10].

Another essential consideration for the multilevel inverter is that the higher the number of voltage steps, the lower the harmonic content of the output. Increasing the number of stages in an inverter not only adds to the amount of components, but also complicates the inverter's control system [2]. As a result, there is a trade-off between voltage steps and inverter control complexity.

The conversion of the input DC supply into the AC supply takes place at the desired frequency and voltage in ordinary two-level inverters with the help of semiconductor power switches. Depending on the setup, four or six switches are used. A group of switches provides the positive half cycle at the output, referred to as positive group switches, while another group provides the negative half cycle, referred to as negative group switches.

II. Multilevel Inverter

The multilevel inverter concept indicates that, from several levels of DC input voltages at the desired level, they generate an AC output voltage waveform. Such DC voltages may or may not be equal at different levels, but the stepped waveform is the AC voltage generated from these DC voltages. The approximation of sinusoidal waveforms from the stepped waveform is one downside of using multilevel inverters. In the staircase output waveform received from the multilevel inverter, sharp transitions are present. In addition to the fundamental frequency of the sinusoidal waveform, the Fourier series principle makes clear that this effect results in harmonics. The harmonics that are produced on the AC side of the system affect the overall power system's power quality. By performing the power conversion in small voltage steps, the power quality of the multilevel inverter is improved. Due to its efficiency, such as lower switching stress (dv/dt) and lower THD on output voltage, the traditional two-level three-phase voltage source inverter (VSI) is widely replaced by its enhanced version called multilevel inverter .

II-A Diode clamped Multilevel Inverter

This inverter mainly uses diodes to limit the power devices voltage stress. The voltage over each capacitor and each switch is V_{dc} . An m level inverter needs $(m - 1)$ voltage sources, $(m - 1)$ capacitors, $2(m - 1)$ switching devices and $(m - 1)(m - 2)$ diodes per leg. To produce a staircase-output voltage, let us consider only one leg of the five –level inverter. The dc rail 0 is the reference point of the output phase voltage.

II-B Flying Capacitor Multilevel Inverter

Capacitors are used in this inverter to limit the voltage of the power devices. The structure of the flying capacitor multilevel inverter is similar to that of a diode clamped multilevel inverter, except that capacitors are utilised to separate the input DC voltage. The voltage across each capacitor and switch is V_{dc} . On the DC bus shape level converter, $(m-1)$ capacitors are required.

II-C Cascaded H-Bridge Multilevel Inverter

The principle of this inverter is to connect H-bridge inverters in series to get a sinusoidal voltage output. The output voltage is the total of the voltages produced by each cell. $(2n+1)$, where n is the number of cells, is the number of voltage output levels. The switching angles can be chosen in such a way that the overall harmonic distortion is decreased. One of the advantages of this type of multilayer inverter is that it has less parts than a clamped diode or a flying capacitor, resulting in a lower price and weight than the two preceding versions [11].

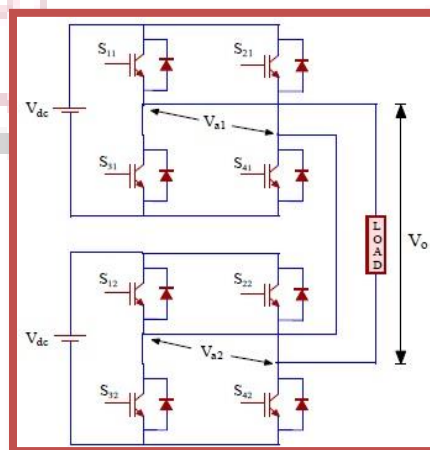


Figure 1: Five Level Cascaded Multilevel Inverter

III. Configuration of Proposed Multilevel Inverter

In the proposed inverter, each transformer will create three voltage levels: zero, $+V_{dc}$, and $-V_{dc}$. The secondary sides of the transformers are connected in series. $+nV_{dc}$ can thus provide the maximum voltage from the setup. Where n is the number of transformers. Different switching states and their corresponding output voltages will be established for the suggested, turn ratios of the transformers will be determined to be the same for the symmetric operation of the inverter. The proposed multilayer inverter has the following key goals:

1. A cascaded multilevel inverter transformer with a reduced number of switching components will be added.
2. The suggested topology utilizes single-phase low-frequency transformers and a source of DC voltage.
3. In contrast with traditional cascaded transformer multilevel inverters, this design will minimize the number of switches.

III – A Amplitude and Harmonic Control

The amplitude of the fundamental frequency is dictated by the dc input voltage for a square wave output from the inverter. The harmonic [12] refers to the integral frequency multiple of any reference signal or wave. The waveform would tend to repeat at a rate corresponding to f Hz if the harmonic signal is shown on an oscilloscope. That is, in the case of the square wave, the strange harmonics are included in the Fourier series and can be portrayed as

$$v_o = \sum_{n_{odd}} \frac{4V_{dc}}{n\pi} \sin n \omega_o t \quad (1)$$

A controlled output can be produced by modifying the switching scheme. An output voltage of the form shown below, has intervals when the output is zero as well as $+V_{dc}$ and $-V_{dc}$. This output voltage can be controlled by adjusting the interval α on each side of the pulse where the output is zero. The rms value of the voltage waveform is

$$V_{rms} = \sqrt{\frac{1}{\pi} \int_{\alpha}^{\pi-\alpha} V_{dc}^2 d(\omega t)} = V_{dc} \sqrt{1 - \frac{2\alpha}{\pi}} \quad (2)$$

The Fourier series of the waveform is expressed as,

$$v_o(t) = \sum_{n_{odd}} V_n \sin(n\omega_o t) \quad (3)$$

Taking advantage of half-wave symmetry, the amplitudes are

$$V_n = \frac{2}{\pi} \int_{\alpha}^{\pi-\alpha} V_{dc} \sin(n\omega_o t) d(\omega_o t) = \frac{4V_{dc}}{n\pi} \cos(n\alpha) \quad (4)$$

Where α is the angle of zero voltage on each end of the pulse. The amplitude of each frequency of the output is a function of α . In particular, the amplitude of the fundamental frequency ($n=1$) is controllable by adjusting α : equation5

$$V_1 = \left(\frac{4V_{dc}}{\pi} \right) \cos \alpha \quad (5)$$

Harmonic content can also be controlled by adjusting α . This is significant because the third harmonic can be eliminated from the output voltage and current. Other harmonics can be eliminated by choosing a value of which makes the cosine term in equation4 to go to zero. Harmonic n is eliminated if,

$$\alpha = \frac{90^\circ}{n}$$

III-B Multilevel Inverter Design

Multilevel inverters have higher power. Instead of one, they are powered by multiple switches. They can use and convert environmentally sustainable energy sources such as wind and solar energy to AC. To convert a DC signal into an AC signal we need fast switching of DC signal giving us multiple levels. This transforms into a wave of stairs that is very similar to a sinusoidal wave.

While changing over from DC voltage to AC voltage, there are two strategies or modes:

1. Either we change over the DC motion into Higher-Power DC flag and after that change over it into AC.
2. We change over DC to AC at the lower level and afterward utilizing line recurrence we get the required yield voltage.

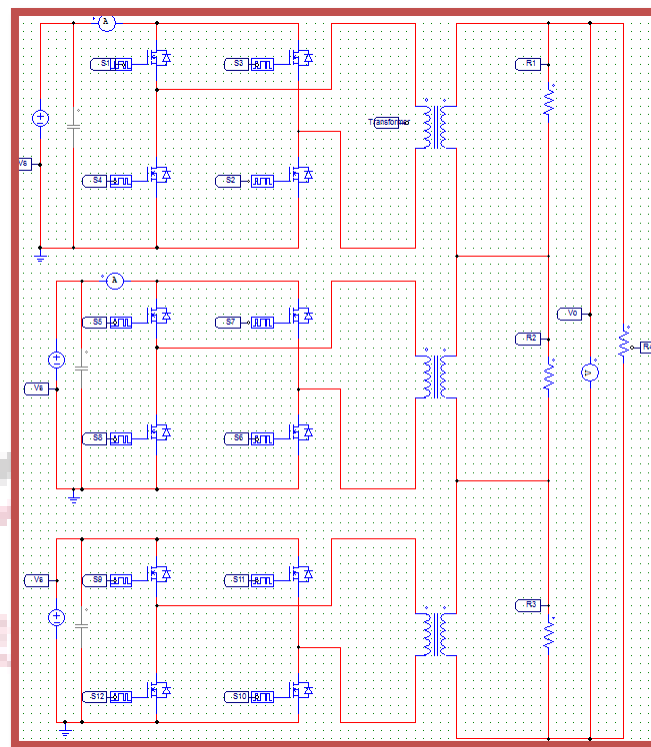


Figure 2: Seven Level Inverter With Transformers

IV. Modulation Techniques

The electronic control gadget in a power converter is turned from one state to the next using balance. All balances are removed to produce a ventured waveform that most closely resembles a flexible reference movement with variable sufficiency, recurrence, and a critical stage section that is normally sinusoidal in a permanent condition. Each topology has distinct altering arrangements in order to obtain the requested yield voltage. Tweak techniques are in charge of integrating reference control signals and preserving them by modifying all voltage sources. The following are the requirements for measuring multilevel change. Outline of seclusion it is not permitted to share different voltage levels at the same time. The quality of the voltage should be excellent. Energy gadgets should be exchanged as little as possible. Power modules can share the heap equally. Control should be measured in a straightforward manner. The cost of use should be as low as possible. In order to combat input voltage variations and meet the demand for voltage/recurrence management, the yield voltage of inverters should be regulated in a variety of modern applications.

The sounds in the yield voltage are determined by the balance scheme selected. When compared to a two-level inverter, using more semiconductor devices and sharing redundancies results in a higher level of unpredictability in multilevel topologies.

V. Simulation Results

In order to validate the analytical result, seven level inverter with transformers has been simulated using PSIM software package platform. The switching angles of gating signal that control the eight switches are obtained as desired and are presented in Fig. 3.

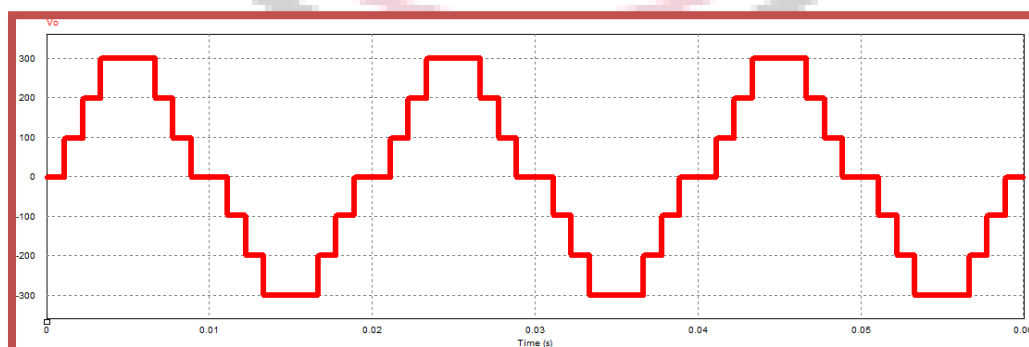


Figure 3(a): Output Voltage (Vo) Waveform

Here we have used 12 sequence wise MOSFET's and related switches. The mode of conduction was 120 degrees. Linked phase wise are perfect transformers. Since it is a three-level inverter, the way switches are switched on and off works accordingly. The capacitors allow the circuit to run smoothly. To make the output flawlessly harmonic, the resistors work finely. The resistor values are 1 ohm and 100 ohm.

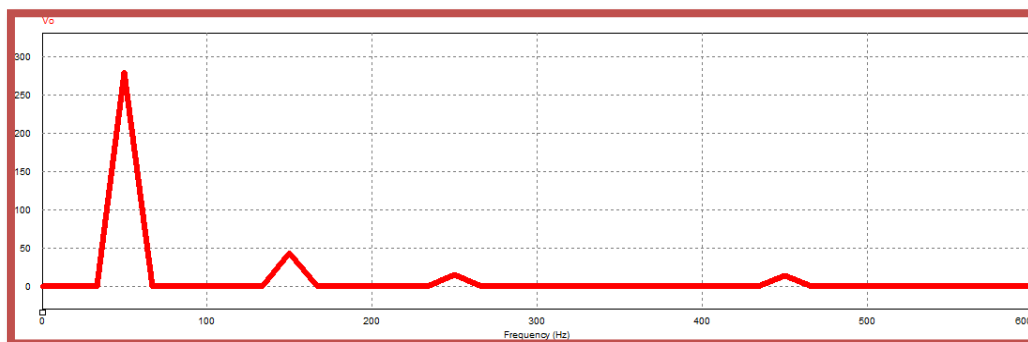


Figure 3(b): Fourier Transform of Figure 3(a)

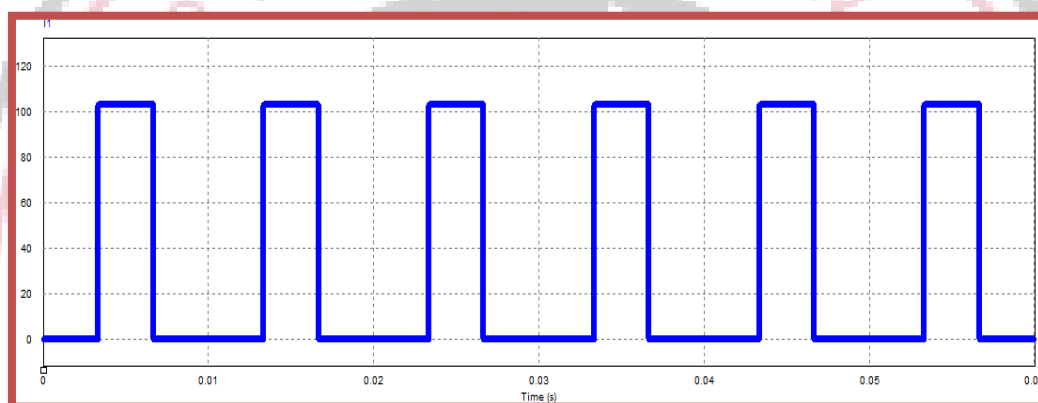


Figure 3(c): Waveform of I_1

VI. Conclusion

Inverters with cascaded H-bridges with different dc sources, clamped (neutral-clamped) diode and flying capacitors (capacitor clamped). In addition, for multilevel inverters such as sinusoidal pulse width modulation (SPWM), selective harmonic elimination (SHE-PWM), space vector modulation (SVM), and others, abundant modulation techniques and control paradigms have been developed. In addition, many multi-level inverter applications concentrate on medium-voltage industrial motor drives, renewable energy system utility interfaces, Versatile AC Transmission System (FACTS) and traction drive systems. We have considered Square wave as outputs in the paper because this is one of the simplest waveforms an inverter configuration can provide and is most suitable for low-affectability applications, such as lighting and warming. The THD of the 7-level inverter output voltage waveform is found to be 1.5 percent lower than the traditional cascade h bridge multilevel inverter. The proposed inverter eliminates the need for a filter. It is also used along with the single DC sources for all the bridge mix.

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