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Harmonics Reduction of a Single Phase Half Bridge Inverter

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HARMONICS REDUCTION OF A SINGLE PHASE HALF BRIDGE INVERTER

Strictly as per the compliance and regulations of :

Harmonics Reduction of a Single Phase Half Bridge Inverter

Imran Azim [α] & Habibur Rahman [α]

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I. Introduction

Dc-to-ac converters are known as inverters. The function of an inverter is to change a dc voltage to a symmetric ac output voltage of desired magnitude and frequency [1]. Some typical applications are variable speed ac drives, induction heating, standby power supplies, uninterruptible power supplies(UPS), traction, HVDC and so forth [2].

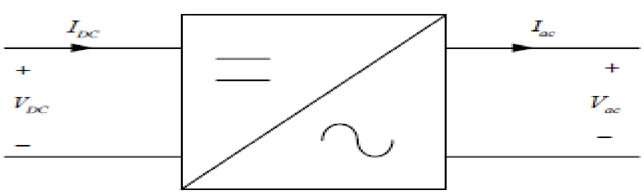

Figure 1 : General Block Diagram of Inverter

Inverters can be broadly classified into two types such as single phase inverters and three phase inverters. The output voltage could be fixed or variable at a fixed or variable frequency. A variable output can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. The output waveforms of an ideal inverter should be sinusoidal. However, the waveforms of practical inverters are non-sinusoidal and contain certain harmonics which can be seen with ease in frequency domain. Due to the availability of high speed power semiconductor devices, the harmonic contents of output voltage can be minimized or reduced significantly by switching technique. BJTs, MOSFETs or IGBTs can be used as ideal switches to explain the power conversion techniques. But IGBT is more popular as it combines the advantages of BJTs and MOSFETs. An IGBT has high input impedance, like MOSFETs, and low on state conduction losses like BJTs [3-4].

Total Harmonic distortion (THD) is a measure of closeness in shape between a waveform and its fundamental component. For improvement purpose, a LC Low pass filter is appended at the output terminal that provides low harmonic impedance to ground [5].

II. Single Phase Half Bridge Inverter

A half bridge inverter consists of a three wire dc source in which $V_s/2$ voltage is obtained across the load as seen in Figure 2. When Q_1 is turned on and Q_2 is turned off, the instantaneous voltage across the load is $V_s/2$ as observed in Figure 2. On the other contrary, if Q_2 is turned on and Q_1 is turned off then according to figure 2. - $V_s/2$ voltage appears across the load. The logic circuit is designed in a way that Q_1 and Q_2 are not turned on at the same. Otherwise, dc source may be shorted out. So, there must a dead time between the switches [6].

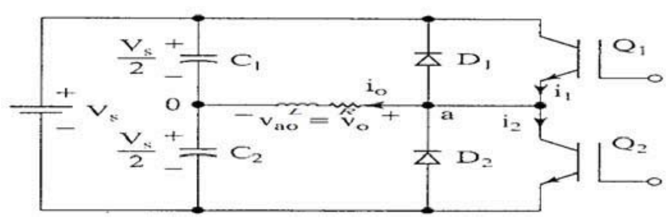

Figure 2 : Circuit Diagram of Single Phase Half Bridge Inverter

Instantaneous inverter output voltage,

$$vo = \sum_{n=1,3...}^{\infty} 2\frac{Vs}{n\pi}\sin nwt \qquad (1)$$

Instantaneous inverter output current,

$$io = \sum_{n=1,3...}^{\infty} 2\frac{Vs}{n\pi\sqrt{R^2+(nwL)^2}}\sin(nwt-\theta n) \qquad (2)$$

III. IGBT

The Insulated Gate Bipolar Transistor (IGBT) is a minority-carrier device with high input impedance and

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large bipolar current-carrying capability. Many designers view IGBT as a device with MOS input characteristics and bipolar output characteristic that is a voltage-controlled bipolar device. To make use of the advantages of both Power MOSFET and BJT, the IGBT has been introduced. It's a functional integration of Power MOSFET and BJT devices in monolithic form. It combines the best attributes of both to achieve optimal device characteristics [6].The IGBT[7, 14] is suitable for many applications in power electronics, especially in Pulse Width Modulated (PWM) servo and three-phase drives requiring high dynamic range control and low noise. It also can be used in Uninterruptible Power Supplies(UPS), Switched-Mode Power Supplies (SMPS), and other power circuits requiring high switch repetition rates. IGBT improves dynamic performance and efficiency and reduced the level of audible noise. It is equally suitable in resonant-mode converter circuits. Optimized IGBT is available for both low conduction loss and low switching loss. Without a hint of doubt an IGBT is the most common device chosen for new power electronics applications. It has highest capabilities up to 1700KVA, 2000V and 800A [8].

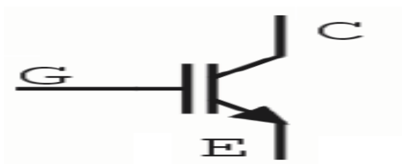

Figure 3 : Circuit Symbol of IGBT

A circuit symbol for the IGBT is shown in Figure 3.

It has three terminals called Collector (C), Gate (G) and Emitter(E).

IV. Harmonics Analysis

A harmonic is a signal or wave whose frequency is an integral (whole-number) multiple of the frequency of some reference signal or wave. The term can also refer to the ratio of the frequency of such a signal or wave to the frequency of the reference signal or wave. Let f represent the main, or fundamental, frequency of an alternating current signal, electromagnetic field, or sound wave. This frequency, usually expressed in hertz, is the frequency at which most of the energy is contained, or at which the signal is defined to occur. If the signal is displayed on an oscilloscope, the waveform will appear to repeat at a rate corresponding to f Hz.

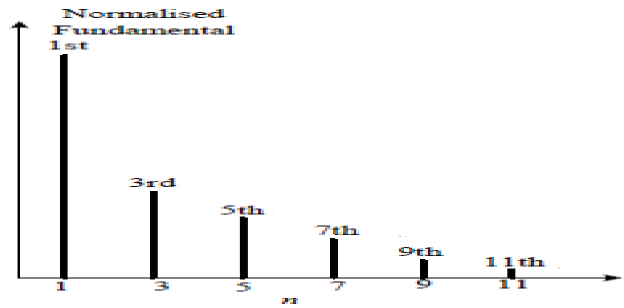

Figure 4 : Harmonic Spectra of an Inverter

As is observed, Harmonic decreases as n increases. It decreases with a factor of (1/n). Even harmonics are absent–Nearest harmonics is the 3rd. If fundamental is 50Hz, then nearest harmonic is 150Hz. Due to the small separation between the fundamental an harmonics, output low-pass filter design can be quite difficult [8].

The effects of harmonics are unpleasant due to the fact that these cause unbalance and excessive neutral currents. Harmonics give rise to interference in nearby communication networks and disturbance to other consumers. In electric motor drives, they cause torque pulsations and cogging [9].

V. Fft Analysis

It is a linear algorithm that can take a time domain signal into the frequency domain and back. Fourier analysis allows a more intuitive look at an unknown signal in frequency domain [10].As is presented in Figure 4. the fundamental component & the harmonic components can be understood without cumbersome.

VI. Thd

Total Harmonic Distortion is a measure of distortion of a waveform. It is given by the expression [11]

$$THD = \sqrt{\frac{Im^2 - Im_1^{\ 2}}{Im^2_{\ 1}}} \qquad (3)$$

Therefore, it is needless to say that THD can be defined as the ratio of the RMS value of all odd number of non fundamental frequency terms to the RMS value of the fundamental [12].

VII. Lc Low Pass Filter

The implementation of an LC filter at the inverter ac terminals could trigger a parallel resonance which tends to amplify the harmonic voltages and currents in ac network leading, in some cases, to potential harmonic instabilities owing to the fact that the filter capacitance has a profound impact on the harmonic performance [8,13].

An LC low pass filter is used to bring the harmonics into a lower state [9].

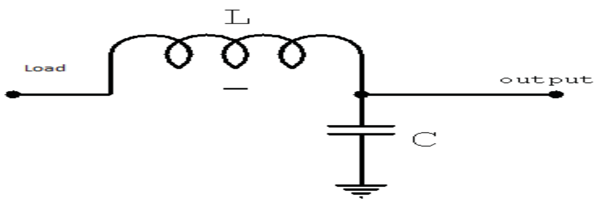

Figure 5 : LC low pass filter

VIII. Simulation and Result

It is assumed that input voltage is 220V. Other necessary parameters are considered deliberately with assuming up to 15th harmonics prevalent at the output so as to [Equation 1 and 2] can be plotted using [10].

According to the illustration, Figure 6. And Figure 7. deal with the inverter output voltage in time domain and frequency domain respectively whereas inverter output current both in time domain and frequency domain have been demonstrated in Figure 8 and Figure 9 respectively.

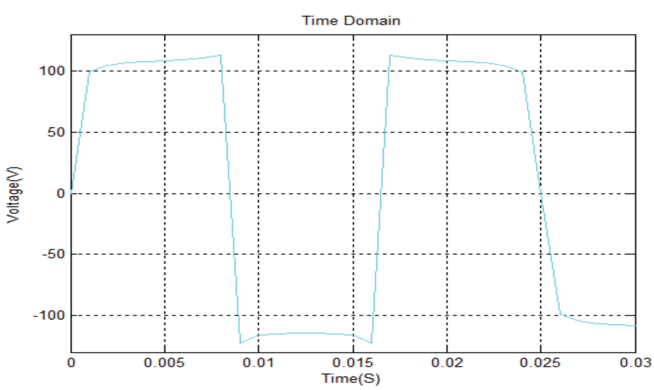

Figure 6 : Time domain Response of Inverter Output Voltage with Harmonics up to 15th

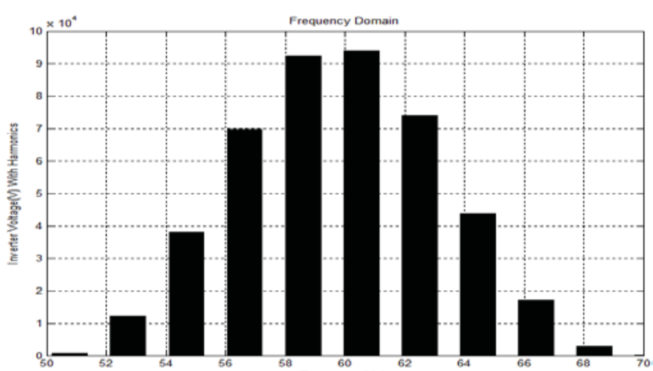

Figure 7 : Frequency domain Response of Inverter Output Voltage with Harmonics up to 15th

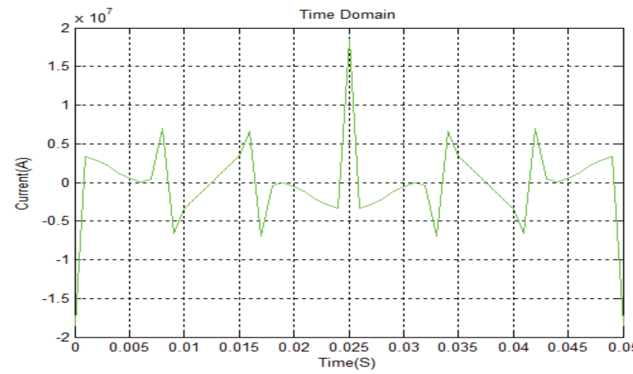

Figure 8 : Time domain Response of Inverter Output Current with Harmonics up to 15th

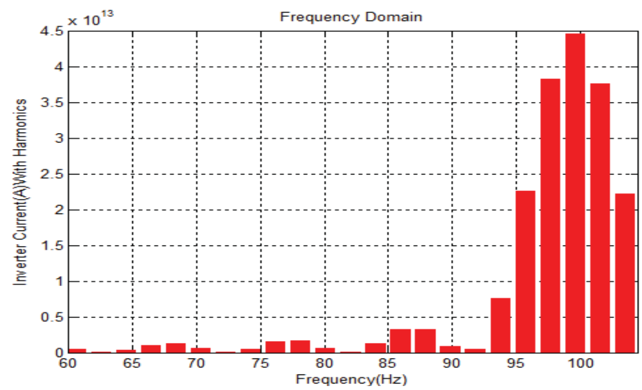

Figure 9 : Frequency domain Response of Inverter Output Current with Harmonics up to 15th

There is no denial that too much harmonics exist at the output even though fundamental frequency is 60Hz. In this case applying [Equation 3] obtained THD is 44.999% which is unquestionably excessive and is needed to be mitigated for better performance. Thence, An LC low pass filter is connected with the load and the output is taken across the capacitance having 10000F value so that it has an effect on the present harmonics.

Finally, the output is plotted using [10] again and nearly a sinusoidal response is observed which has been depicted in Figure 10. Furthermore, from frequency domain response described in Figure 11, it is found that the fundamental component has the highest amplitude.

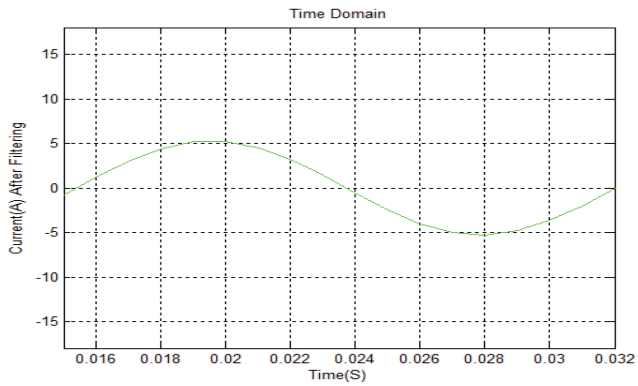

Figure 10 : Time domain Inverter Output Response after appending an LC low pass Filter

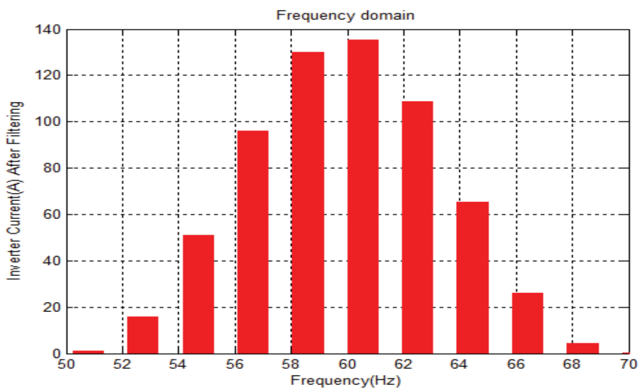

Figure 11 : Frequency domain Inverter Output Response after appending an LC low pass Filter

Here, calculted THD is 0.0183%.

IX. Result and Discussion

At normal condition, when up to 15th harmonics are considered then there exists 44.999% THD. But as soon as an LC low pass filter is implemented it has been dropped to 0.0183%. Therefore, a vast improvement has been noticed.

A single phase half bridge inverter finds an extensive utilization in variable speed ac drives, induction heating, standby power supplies, uninterruptible power supplies(UPS), traction, HVDC, grid connection of renewable energy sources and so on due to simple design and cost effective aspects. However, unlike single phase full bridge inverter the maximum ac voltage is limited half the value of full dc voltage source. Again it may need a center tapped source. Now, if it is intended to get higher ac voltage then a step up transformer can be used.

In coming days, using this concept, the output responses of single phase full bridge inverter can be observed as well as the harmonics occurred at the output can be minimized by applying LC low pass filter. An implementation of 2nd order LC low pass filter would be interesting in this case.

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