Abstract - This paper concentrates on modelling and simulation of single phase inverter as a frequency changer modulated by Pulse Width Modulation (PWM). An inverter is a circuit that converts DC sources to AC sources. Pulse Width Modulation is a method that utilization as an approach to abatement add up to harmonic distortion in inverter circuit. The model is executed utilizing MATLAB/Simulink software with the SimPower System Block Set in light of PC simulation. PC simulation assumes an imperative part in the plan, investigation, and assessment of force electronic converter and their controller. MATLAB is a successful instrument to examine a PWM inverter. Preferences of utilizing MATLAB are the accompanying: Faster reaction, accessibility of different simulation devices and utilitarian squares and the nonappearance of joining issues. Safe-replacement methodology need be actualized is to explain exchanging Transients. In this way, Insulated Gate Bipolar Transistor (IGBT) is use as exchanging gadgets. IGBT is ideal since it is anything but difficult to control and low misfortunes. The outcome from Simulink was checked utilizing MATLAB simulation.

Keywords: PWM, Duty cycle, Harmonics, THD, MATLAB SIMULINK

Introduction
The term harmonics alluded to Power quality in perfect world would mean how unadulterated the voltage is, the way immaculate the present waveform is in its sinusoidal frame. Control quality is essential to business and modern power framework outlines. In a perfect world, the electrical supply ought to be an impeccable sinusoidal waveform with no sort of distortion. On the off chance that the current or voltage waveforms are bended from its optimal frame it will be named as harmonic distortion. This harmonic distortion could come about on account of numerous reasons. In this day and age, prime significance is given by the specialists to determine a strategy to lessen the harmonic distortion. Harmonic distortion was less in the past when the plans of force frameworks were extremely basic and preservationist. Be that as it may, these days with the utilization of complex outlines in the business harmonic distortion has expanded also. This venture clarifies the impacts of Harmonics in the Power System and ventures to lessen the impacts of Harmonics. This venture will likewise clarify how Harmonic distortion is a standout amongst the most imperative issues connected with power quality and makes a few unsettling influences to the Power System. It incorporates the Harmonic diminishment strategies to enhance the power quality and it will likewise incorporate the simulation for the same. This venture additionally clarifies distinctive sorts of inverters that are utilized as a part of the Power System. Amid the change from DC to AC, harmonics influence the power quality a great deal. How harmonic diminishment will enhance the power quality will be clarified in detail. Clients (PU)’s. This crafty utilization of the range prompts to new difficulties to the changing accessible range. Utilizing a Trust-Worthy calculation, it enhances the reliability of the Spectrum sensing in CR-Networks.
I. Literature Survey

1.1. Inverter

An electrical device that converts DC power into AC power at coveted yield voltage and frequency is called an Inverter. Phase controlled converters when worked in the inverter mode are called line commutated inverters. Be that as it may, line commutated inverters require at the yield terminals a current AC supply which is utilized for their replacement. This implies line commutated inverters can't work as separated AC voltage sources or as factor frequency generators with DC power at the info. In this way, voltage level, frequency and waveform on the AC side of the line commutated inverters can't be changed. Then again, drive commutated inverters give an autonomous AC yield voltage of movable voltage and movable frequency and have accordingly much more extensive application.

Inverters can be comprehensively characterized into two sorts in view of their operation:

- Voltage Source Inverters (VSI)
- Current Source Inverters (CSI)

Voltage Source Inverters is one in which the DC source has little or immaterial impedance. At the end of the day VSI has firm DC voltage source at its information terminals. A present source inverter is bolstered with movable current from a DC wellspring of high impedance, i.e. from a firm DC current source. In a CSI encouraged with firm current source, yield current waves are not influenced by the load. From view purpose of associations of semiconductor gadgets, inverters are named under

- Bridge Inverters
- Series Inverters
- Parallel Inverters

1.2. Single Phase Half Bridge

It comprises of two semiconductor switches T1 and T2. These switches might be BJT, Thyristor, and IGBT and so on, with a recompense circuit. D1 and D2 are called Freewheeling diode otherwise called the Feedback diodes as they criticism the load reactive power.

![Fig. 1 Circuit Diagram of Single Phase Half Bridge Inverter](image)

1.3. Full Bridge VSI Inverter

The switches are T1, T2, T3 and T4. The switches in every branch is worked on the other hand so they are not in same mode (ON/OFF) at the same time. Practically speaking they are both OFF for brief timeframe called blanking time, to maintain a strategic distance from short-circuiting. The switches T1 and T2 or T3 and T4 ought to work in a couple to get the yield. These scaffolds legs are exchanged with the end goal that the yield voltage is shifted starting with one then onto the next and thus the adjustment in extremity happens in voltage waveform. In the event that the shift angle is zero, the yield voltage is additionally zero and maximal when shift angle is π.

![Fig. 2 Single Phase Full wave Bridge Inverter](image)
II. PWM (Pulse Width Modulation Technique)

Pulse width regulation (PWM) is a powerful strategy for controlling simple circuits with a processor's advanced yields [8]. The utilizations of PWM are wide assortment utilized like going from estimation and interchanges to power control and change. PWM gives an approach to diminish the Total Harmonic Distortion (THD) of load current. The THD prerequisite can be met all the more effortlessly when the yield of PWM inverter is separating. The unfiltered PWM yield will have a generally high THD, yet the harmonic will be at the much higher frequencies than for a square wave, making sifting effectively. The aggregate harmonic distortion, or THD, is characterized as the proportion of the total of the powers of every single harmonic segment to the power of the central. In simple circuit; simple flag has a consistently differing esteem, with vast determination in both time and size. For instance of a simple gadget for 5 volt battery, yield voltage is not definitely 5V, changes after some time, and can take any genuine numbered esteem. The measure of current drawn from a battery is not constrained to a limited Analog signs are discernible from advanced signs in light of the fact that the last dependably take values just from a limited arrangement of foreordained potential outcomes, for example, the set \{0V, 5V\}. Simple voltages and streams can be utilized to control things specifically, similar to the volume of an auto radio. In a straightforward simple radio, a handle is associated with a variable resistor. As the handle is turned, the resistance goes up or down. As that happens, the present coursing through the resistor increments or reductions. This progressions the measure of current driving the speakers, subsequently expanding or diminishing the volume. A simple circuit is one, similar to the radio, whose yield is straightly corresponding to its information .The simple control framework it is not generally monetarily alluring or generally common sense. Simple circuits tend to float after some time and can, hence, be extremely hard to tune. Accuracy simple circuits, which take care of that issue, can be vast, substantial, and costly. Simple circuits can likewise get exceptionally hot; the power disseminated is corresponding to the voltage over the dynamic components increased by the current through them. Simple circuitry can likewise be touchy to commotion. In view of its unbounded determination, any irritation or clamor on a simple flag fundamentally changes the present esteem. In the event that the simple circuit is controlled digitally, the framework expenses and power utilization can be definitely decreased. Moreover, there are numerous microcontrollers and DSPs as of now incorporate on-chip PWM controllers, making execution simple. PWM is a method for digitally encoding simple flag levels. The obligation cycle of a square wave is modulated to encode a particular simple flag level by utilizing the high-determination counter. The PWM flag is still computerized on the grounds that, at any given moment of time, the full DC supply is either completely on or completely off. The voltage or current source is provided to the simple load by method for a rehashing arrangement of on and off heartpulses. The on-time is the time amid which the DC supply is connected to the load, and the off-time is the period amid the supply is turned off. Given an adequate data transmission, any simple esteem can be encoded with PWM. Control of the switches for the sinusoidal PWM yield requires a reference flag (tweaking or control flag) which is a sinusoidal wave and a bearer flag which a triangular wave that control the exchanging frequency. There two kind of the exchanging for PWM, unipolar exchanging and bipolar exchanging. In a unipolar exchanging plan for PWM, the yield is changed from either high.
III. HARMONICS

3.1. Introduction to Harmonics

Any periodic wave form can be represented by infinite series of sinusoids

\[ f(t) = a_0 + \sum_{n=1}^{\infty} \left( a_n \cos(nwt) + b_n \sin(nwt) \right) \]  

where

\[ a_n = \frac{2}{T} \int_{0}^{T} f(t) \cos(nwt) \, dt \]
\[ b_n = \frac{2}{T} \int_{0}^{T} f(t) \sin(nwt) \, dt \]

Harmonics have direct been a greater amount of an issue these days because of the expanded use of nonlinear loads which are the reason for harmonics. The non-straight loads here allude to loads which current is not relative to the connected voltage. It must be noticed that diverse non-straight loads will have distinctive slight voltage current attributes. Some of the time a slight increment in voltage can bring about the current to twofold. Any occasional, misshaped waveform can be communicated as an entirety of immaculate sine waves in which the frequency of every sinusoid is a number numerous of the crucial frequency (50Hz for Australia). This different is called harmonic of the principal. Harmonic are regularly investigated up to the 40th different or part however the couple of odd, prior harmonic segments (third, fifth, seventh) are the ones that have noteworthy impact on the framework. What separate a bended harmonic waveform and any waveform distortion is that those brought on by harmonics are intermittent and can be part into harmonics segments.

3.2. Voltage and Current Distortion

Nonlinear loads are the sources of harmonic current bringing about twisted current waveforms. Voltage distortion is the aftereffect of mutilated streams going through the direct, arrangement impedance of the power conveyance framework. In this way, it is dependably the present distortion that outcomes in voltage distortion. By the by, it must be noticed that loads have distortion no power over the voltage distortion. A similar load in two unique areas on the power framework will bring about two diverse voltage distortion values.

3.2.1. Even Harmonics

Even harmonics (second, fourth, and sixth) are less inclined to happen at levels inconvenient to electrical frameworks. This is on the grounds that non-direct loads ordinarily produce odd harmonics instead of even harmonics. Besides, when both the positive and negative half cycles of a waveform are comparative fit as a fiddle, the Fourier arrangement contains just odd harmonics.

3.2.2. Odd Harmonics

Odd harmonics (third, fifth, and seventh) are more normal in power frameworks and are the ones which prompt to serious outcomes on the off chance that they are not controlled. Each odd harmonic is connected with one of the grouping part (positive, negative or zero). The phase arrangement is critical in light of the fact that it decides the impact of the harmonic on the operation of the electrical gear. Table 1 demonstrates the harmonics with their related phase succession.

3.3. Causes for HARMONICS

Harmonics are brought on by non-straight loads that are loads that draw a non-sinusoidal current from a sinusoidal voltage source. Some cases of harmonic creating loads are

- Electric circular segment heaters
- Static VAR compensators
- Inverters
- DC converters
- switch-mode power supplies and AC or DC engine drives

This venture Report manages the Harmonic examination of Single Phase inverter with Pulse Width Modulation (PWM). It incorporates both basic and pragmatic inverter. The Simulink demonstrate for both straightforward and down to earth inverter has been mimicked in MATLAB. Its different
parameters, for example, R, C and Filter plan. These parameters are shifted and the subsequent voltage and current diagrams has been examined.

IV. Simulation Results

Simulation model have been designed and implemented in MATLAB SIMULINK tool. The proposed Simulink model has been shown in figure 3, in which modelling and simulation of single phase inverter as a frequency changer modulated by Pulse Width Modulation (PWM) has been designed. Load voltage, load current and switching pulses have been shown in figure 4. The Simulink demonstrate for both straightforward and down to earth inverter has been mimicked in MATLAB. Its different parameters, for example, R, C and Filter plan. These parameters are shifted and the subsequent voltage and current diagrams has been examined.

![Simulink model of proposed system](image1)

Fig. 3 Simulink model of proposed system

![Load voltage, current and switching pulses](image2)

Fig. 4 load voltage, current and switching pulses
V. Conclusion

This article deals with the Harmonic analysis of Single Phase inverter with Pulse Width Modulation (PWM). It includes both simple and practical inverter. The Simulink model for both simple and practical inverter has been simulated in MATLAB. Its various parameters such as R,C and Filter design. These parameters are varied and the resulting voltage and current graphs has been studied.

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