Hardware Implementation of SPWM technique for Three Phase Voltage Source Inverter using comparator with comparison of simulation result

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Abstract—

a) : **Paper deals with study of a Sinusoidal Pulse Width Modulated Inverter. The function of Inverter is to convert a DC voltage at it's input to AC voltage with a fixed frequency e.g., 50Hz in India. This Paper presents the simulation of Three phase voltage switching inverter in PSIM along with hardware result. SPWM technique is used for providing the gate pulse to the IGBT. In SPWM the sine wave is compared to the triangle wave of frequency 3KHz to generate the SPWM. The generated pulses is given to the IGBT to trigger the IGBT. This method is popularly used in speed control of three phase induction motors. The load taken here is resisitive (R) .**

KEYWORDS: IGBT,SPWM,PSIM,Three phase inverter

I. INTRODUCTION

a) : Speed control of AC motors evolved very rapidly with advances in power electronics technology. Applications that were dominated by DC motors became most suited for AC motors as a more economical alternative.For applications with varying loads, a variable-speed drive is a must since it can achieve up to 50savings.

b) : What if we cannot use the stored power in a battery when we don't have power supply. Since the energy stored in a battery is in dc form so to use this stored power in battery we need to convert this dc form of energy to ac form. So here comes the concept of power inverters. The devices which can convert electrical energy of DC form into AC form is known as power inverters. They come in all sizes and shapes, from a high power rating to a very low power rating, from low power functions like powering a car radio to that of backing up a building in case of power outage. Inverters can come in many different varieties, differing in power, efficiency, price and purpose.

c) : DC-AC inverters have been widely used in industrial applications such as uninterruptible power supplies, static frequency changes and AC motor drives. Recently, the inverters are also playing important roles in renewable energy applications as they are used to link a photovoltaic or wind system to a power grid. Like DC-DC converters, the DC-AC inverters usually operate in a pulse width modulated (PWM) way and switch between a few different circuit topologies, which means that the inverter is a nonlinear, specifically piecewise smooth system. In addition, the control strategies used in the inverters are also similar to those in DC-DC converters.

II. PULSE WIDTH MODULATION(PWM)

In Pulse Width Modulation (PWM) technique, pulses of constant amplitude but different duty cycles are generated by modulating the time periods . This modulation is done by using one carrier and one reference signal . These two signals are given to a comparator and the corresponding signals are generated based on the logic of the comparator. The reference wave is the desired signal output which may be a sine wave or a square wave. The carrier wave , on the other hand , is generally sawtooth or triangular wave having frequency higher than that of the reference signal. Advantages of using PWM technique:

1) Any additional component is not required for the control of the output voltage.
2) Lower order harmonics are significantly reduced.

There are three basic PWM techniques:

1) Single pulse
2) Multiple pulse
3) Sinusoidal

This paper focuses on Sinusoidal PWM technique.

III. BLOCK DIAGRAM

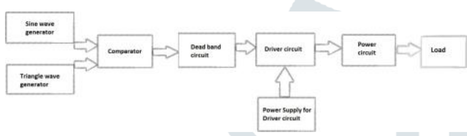

Fig. 1. Block Diagram

The three phase sine wave is generated from the 230V 50Hz supply. The generated signal has a fix frequency.This is the reference signal which is given to the non-inverting terminal of the opamp working as a comparator. The triangle wave as a carrier is given to the inverting terminal of the opamp. The magnitude of the carrier wave should always be higher than the reference signal. The frequency of the carrier wave is in several kHz(2kHz), whereas the frequency of the sine wave is fixed 50hz.

The opamp working as a comparator compares the two signals and gives the output signal, which is SPWM. This SPWM is inverted and given to the gate of the six IGBTs.

To avoid the turning on of the two IGBTs of the same leg dead band circuit is used, which provides the dead time of several micro seconds between the two pulses. The signal from the dead band circuit cannot be directly given to the power circuit. An isolation circuit (gate driver circuit) is required betweem the two. The power circuit comprises of six IGBTs. Seperate power supply is required for the gate driver circuit.

IV. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

SPWM techniques have constant amplitude pulses with different duty cycles for each period. The width of these pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content . Sinusoidal pulse width modulation is the mostly used method in motor control and inverter application . In SPWM technique triangle carrier wave is compared to the the three phase shifted sine wave using opamp as a comparator . Generally, three sinusoidal waves are used for three phase inverter. For SPWM the three sine wave is compared to the triangle wave. The opamp as a comparator is used to compare the two signals. The triangle wave is applied to the inverting terminal of the opamp and sine wave is applied to the non-inverting terminal. The peak to peak voltage of triangle wave is taken 8V and that of sine wave is take 6V. The magnitude of carrier wave should always be greater than the reference signal. The frequency of triangle wave(2KHz) is kept higher than the sine wave(50Hz) . Conventional SPWM signal generation technique for three phase voltage source inverter is shown in Figure 1.

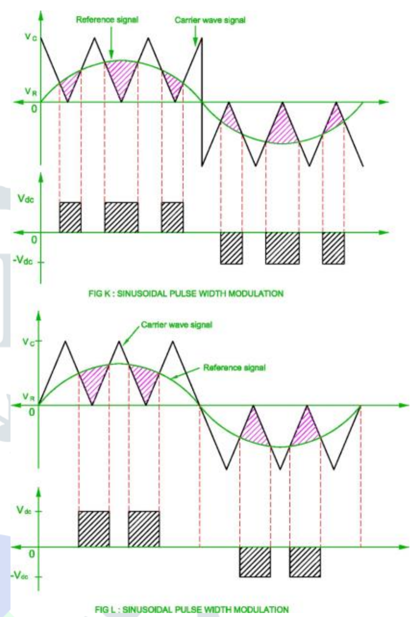

Fig. 2. SPWM

V. CONTROL CIRCUIT

A. *Triangle wave generator*

1) Simulation result: Triangle wave generator has two parts comparator and integrator

The output from the comparator is square wave which is applied to the inverting terminal of the integrator. Output from the integrator is triangle wave which is then fed back as a input to the comparator through voltage divider. Resistor and capacitor of suitable values are selected according to the frequency of the triangle wave

R3=1k, R2=20K, R3=10K(pot).

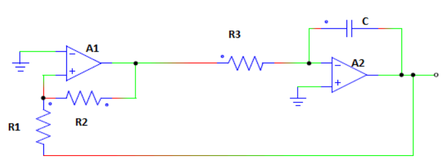

Fig. 3. Triangle wave generator

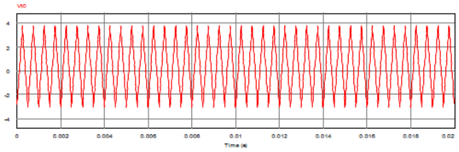

Fig. 4. Triangle wave

2) Hardware result: The circuit given (fig 5) is implemented according to the simulation ckt (fig 3). The values are taken as mentioned in the simulation part. The frequency of the triangle wave is 2kHz(approx).IC UA741 is used. This circuit operates on dual power supply of +15 and -15V. The output of Triangle wave circuit (fig 5) is as follows:

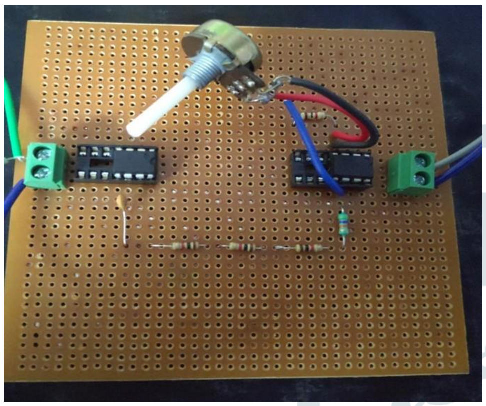

Fig. 5. Triangle wave

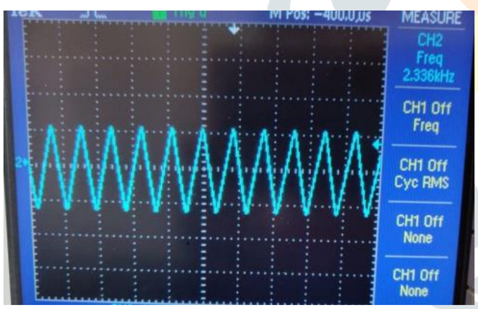

Fig. 6. Triangle wave output of hardware circuit

B. SINE WAVE GENERATOR

1) Simulation Result: Circuit of sine wave generator is as follows:

The working of circuit(fig 4) is as follows:The input sine wave gets inverted and buffered by unity gain opamp A1.Now its output becomes the master signal.

The master signal gets inverted again and buffered by unity gain opamp A2.This output becomes phase1 with 0 degree phase

The master signal is phase shifted 60 degrees by RC network R1C1 and applied to amplifier A4.It is non-inverting amp with a gain of two to compensate for the signal loss in RC netwrok.

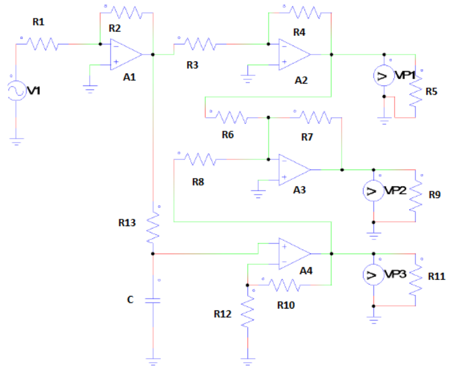

Fig. 7. Sine wave generator

Because the master signal has a phase shift of 180 degrees from the input signal, and is shifted additionally 60 degrees by the RC network,the final signal is shifted 240 degrees and becomes the third phase. Unity gain amp A3 adds phase 1 (0 degrees) and phase 3(240 degrees), giving a 300 degree phase shifted signal. This is inverted, effectively shifting the phase an additional 180 degrees, giving the 120 degrees phase 2 signal.

The circuit operates at fixed frequency

R1=R2=R3=R4=R5=R6=R7=R8=R9=R10=R12=10kOhms

R13=5.6kOhms

C1=1000nF

VP1=O degrees, VP2=120 degrees, VP3=240 degrees .

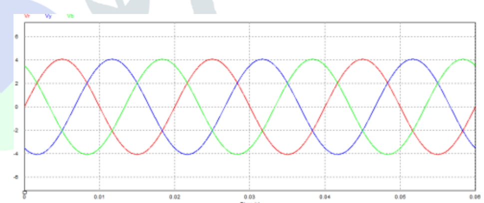

Fig. 8. Three phase sine wave

2) Hardware Implementation: The circuit is implemented according to the simulation. The values of resistors and capacitors are chosen accordingly.LM324 ic is used which consists of four opamps

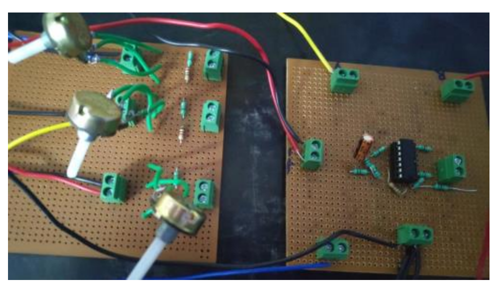

Fig. 9. Triangle wave

The Pot of 10k is kept to adjust the magnitude of sine wave . The output of the circuit is as given below:

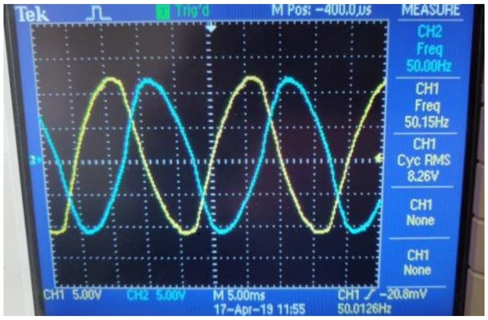

Fig. 10. sine wave

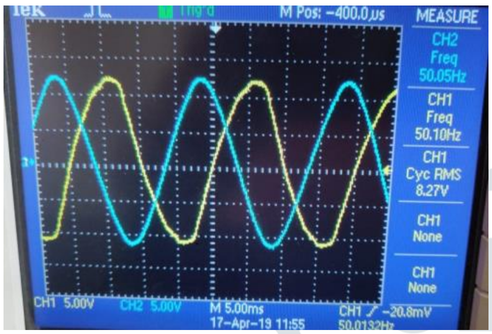

Fig. 11. Triangle wave

VI. SPWM

1) In PSIM: Triangle wave of frequeny 2KHz is used as a carrier signal which is compared to the three phase sine wave of frequency 50Hz using comparator.

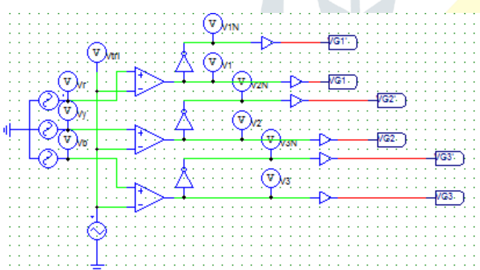

Fig. 12. SPWM generation using comparator

The output of comparator is given in fig 6, fig 7, fig 8

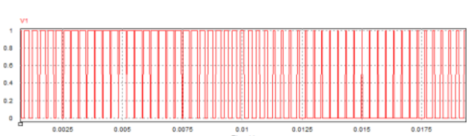

Fig. 13. Output of phase 1

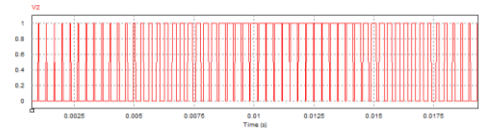

Fig. 14. Output of phase 2

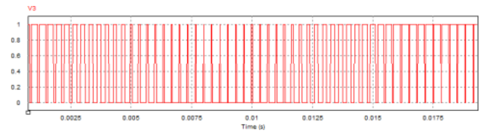

Fig. 15. Output of phase 3

2) Hardware Implementation: For the comparator circuit LM324 ic is used which consists of four opamps, out of which three are being used. The output from the sine wave generator and triangle wave generator is given to LM324 ic. This ic has a separate power supply of 15V.

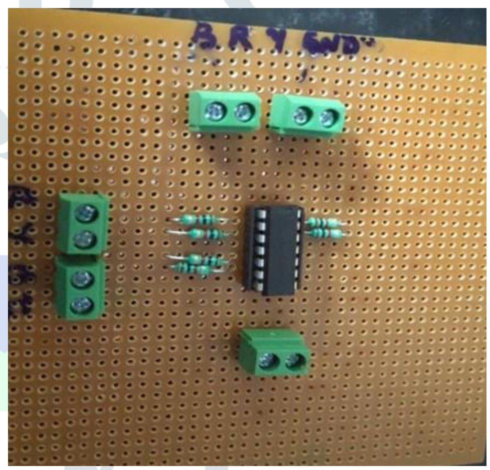

Fig. 16. Triangle wave

The output of the comparator LM324 is as follows:

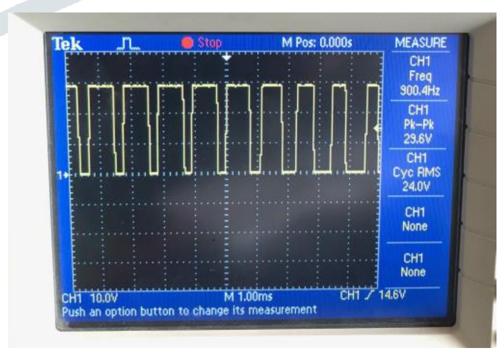

Fig. 17. Triangle wave

Similarly we will get the output of other two phases. The three outputs are inverted and given to the six IGBTs

VII. DEAD BAND

The output from the comparator cannot be directly given to the IGBT as there is a high chance of turning on of the two IGBTs of the same leg which results in short circuit and eventually damages the power circuit. So to prevent this from happening the dead time is provided between the two signals. Time delay depends upon the value of the R and C.The circuit is implemented using NAND gate ic CD4093
Time Delay=R*C.

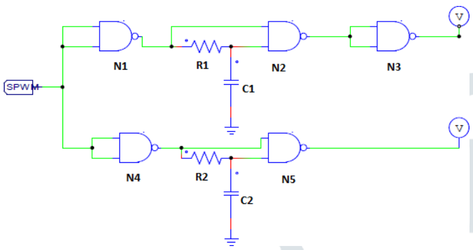

Fig. 18. Dead Band Simulation Circuit

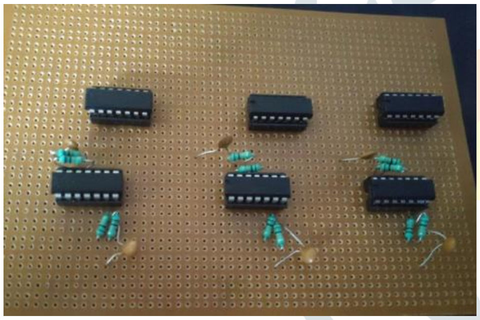

Fig. 19. Dead Band Hardware Circuit

The output of the circuit is as follows

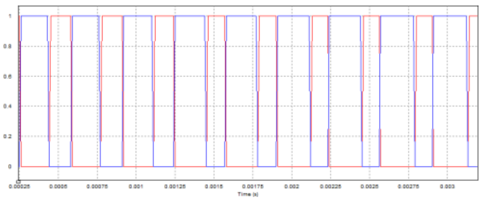

Fig. 20. Simulation Output Result of Dead Band Circuit

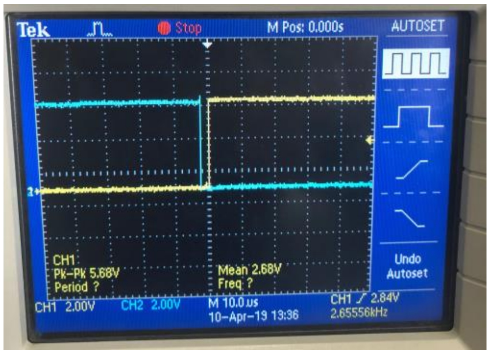

Fig. 21. Hardware output of Dead Band Circuit

VIII. CONCLUSION

From the above results and waveforms it is seen that opamp/analog generated SPWM works accurately. The Hardware result is similar to that of simulation result. From the simulation result it can be concluded that SPWM technique is the efficient way of contolling the speed of the three phase induction motor.

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