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Implementation of DSP Based Voltage Source Inverter (VSI) by using Sinusoidal Pulse Width Modulation Technique.

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Abstract: ***This paper deals with theoretical and practical outlook related to implementation of a Digital signal processor (DSP) based on Sinusoidal Pulse Width Modulation (SPWM). For single phase inverter, sine wave is taken as reference signal and saw tooth is taken as carrier signal. It is developed by TMS320F28027 piccolo*** ^{TM} ***microcontroller with the help of simulink model. TI Texas instrument TMS320 is a blanket name for a series of DSP from Texas instrument. Through the TMS32010 processor which was faster in the DSP market and we use C2000 series microcontroller family with performance integrated peripherals designed for real – time control applications like motor drive control, industrial automation, solar and other renewable energy sources. The voltage source inverter is used in motor speed control and in solar, wind power grids. The system is verified by experimenting in simulation.***

Index Terms**: Digital Signal Processor (DSP), Sinusoidal Pulse Width Modulation (SPWM), Total Harmonic Distortion (THD), Voltage Source Inverter (VSI).**

I. INTRODUCTION

An instrument is used to convert the DC power to AC power with required output voltage and frequency is called inverter. The classification of inverter is based on the type of the supply i.e. Voltage source inverter (VSI) and Current source inverter (CSI). VSI has DC voltage as source at its input side and for CSI it is DC current as input. Pulse Width Modulation technique (PWM) is used to control VSI. PWM method is most efficient control method for inverters. Constant DC voltage is applied as input and the controlled AC output voltage is obtained by changing ON – OFF time periods of inverter switches. Advantages of PWM are voltage control is done without requirement of any additional components and Lower Order Harmonics (LOH) can be eliminated. By using this technique Total Harmonic Distortion (THD) can be reduced. For Higher Order Harmonics (HOD) can be reduced by using filter circuit. It is easy to filter with filter circuit. In SPWM the number of pulses is counted for every half cycle. A high frequency saw tooth waveform is used as carrier wave (V_c), is compared with sinusoidal reference wave (V_r) which has low frequency. The output pulses are not identical as these pulses have variable width. The width of the pulses varies in accordance with magnitude of sine wave. The frequency of carrier wave is f_c and reference frequency f_r. The number of pulses for half cycle is

$$N = fc / 2f_r \ldots\ldots\ldots (1)$$

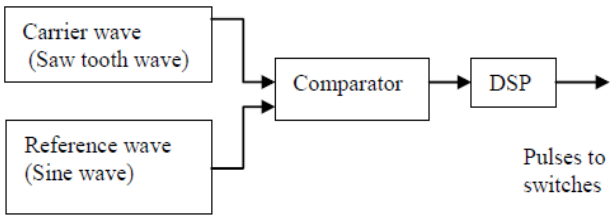

Fig 1

The TMS320F28027 launch pad is used for DSP based SPWM. SPWM is advanced control technique it has many advantages such as the power losses in the switching devices are less, when the switch there will be no voltage drop in the switch and when it is off, there will be no current flow in the switch. Therefore the power losses will be no power losses in the switch. SPWM works on digital control so with this we can vary duty cycle easily.

II. BASIC VOLTAGE SOURCE INVERTER

The input of VSI is a constant DC source for positive half cycle of output. Switches (S_1, S_2) are closed i.e. they are conducting state and switches (S_3, S_4) are opened so they are in non conducting state. To obtain negative half cycle in the output, switches (S_3, S_4) are closed and switches (S_1, S_2) are opened.

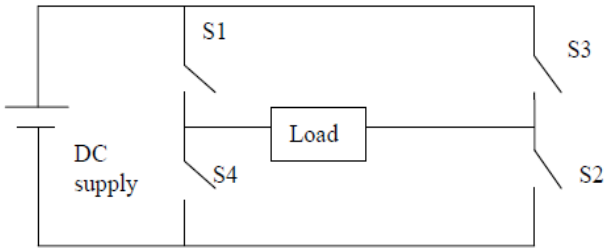

Fig. 2

For the filtering purpose of LC filter is used. This filter is used to reduce the higher order harmonics and to make output signal as sinusoidal. The load is resistive in nature.

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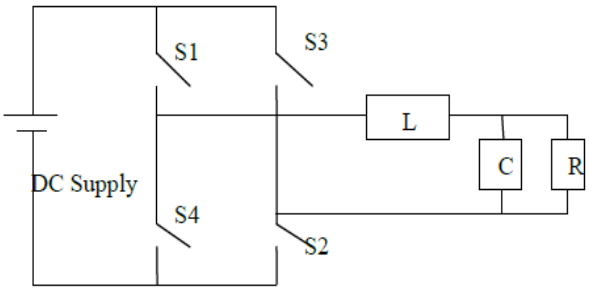


Fig.3 Basic Inverter Circuit with LC filter.

Rules of SPWM

The output voltage Vo and supply voltage is Vs. The gating signal is generated by the intersection of sawtooth carrier signal with sinusoidal reference signal. The g_1,g_4 are the gating signals. $Vo=Vs(g_1-g_4)$, however g_1,g_4 cannot be released at same time. Sinusoidal reference signal is denoted as Vr. Vr=VrSinwt. It can be observed that each pulse area is equal to area under sine wave between adjacent midpoints of off periods on gating signal. If δ_m is width of m^{th} pulse, the RMS output voltage by summing the average areas under each pulse

$$Vo=Vs\ (\sum\delta_m/\pi)^{1/2} \ldots\ldots\ (2)$$

The fourier coefficient of output voltage is

$$Bn = \sum_{m=1}^{2p} \frac{4Vs}{n\pi} \sin\frac{n\delta m}{2}\left[\sin\left(\alpha_m + \frac{\delta_m}{2}\right)\right]$$

$$\ldots\ldots\ldots(3)$$

The m^{th} time and angle α_m of intersection can be determined

$$T_m=\alpha_m/\omega \ldots\ldots\ (4)$$

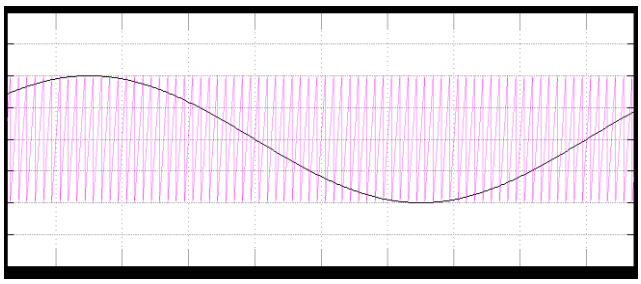


Fig.4 SPWM wave form

The width of m^{th} pulses dm can be found as

$$Dm=\delta_m/\omega=t_{m+1}-t_m\ldots\ldots\ (5)$$

The output voltage of inverter harmonics and the PWM pulse harmonics are in a high frequency range and around switching frequency (f_c). Its multiples are mf, 2mf, 3mf and so on. The frequencies at which voltage harmonics can be related as

$$f_n=(jmf\pm k)f_c \ldots\ldots\ldots(6)$$

The peak fundamental output voltage for PWM and SPWM constant can be approximately $Vm_1=dVs \ldots..\ (7)$

For d=1→ gives maximum peak amplitude
$Vm_1(max)=4Vs/\pi=1.273Vs$

The operation beyond d>1 is over modulation. Over modulation leads to harmonics.

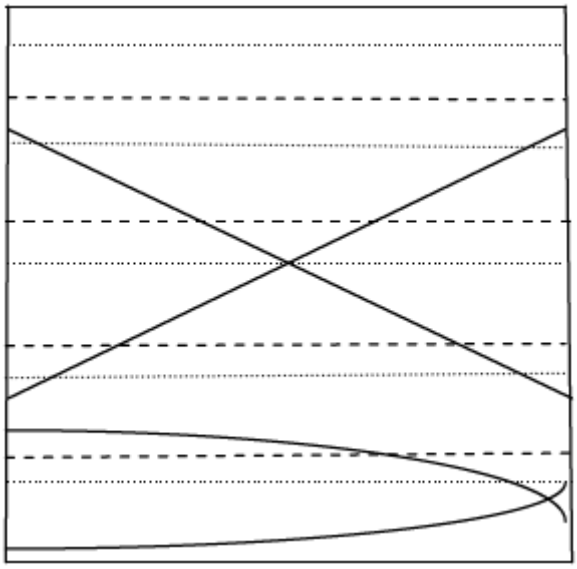


Fig.5 Modulation index

The above figure shows about the distortion factor. The distortion factor is used to measure the amount remains in the output voltage waveform, after the waveform has been subjected attenuation (divided by n^2).

III. BASICS OF DSP TECHNIQUE

DSP technique has greater advantages comparing to other techniques. It has high accuracy, cheaper price, ease of high data storage, flexible in configuration, applicable to low frequency systems.

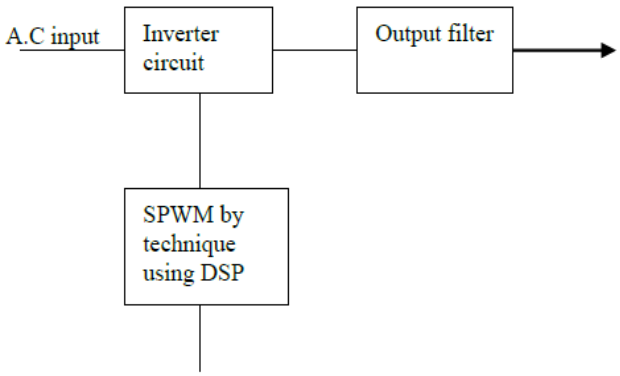


Fig.6 Inverter circuit with DSP control

DSP has some limitations. This system is very complex system because it consists of analog to digital converters and digital to analog converters with their filter association. The power consumption is high because DSP chip has lakhs of transistors. The power dissipation is 1watt. The speed of operation is less because of A/D and D/A converters. The TMS320F28027 launch pad is used for DSP based SPWM. This launch pad is C2000™ 32-bit micro controller is used for real time control like induction motor drive, electrical vehicles and solar inverters.

Fig 6 TMS320F28027 Launch Pad

IV. SIMULATION RESULTS

To implement single phase voltage source inverter matlab software is used. By comparing sinewave and sawtooth wave pulses are generated. And its complimentary pulses are obtained by using NOT gate.

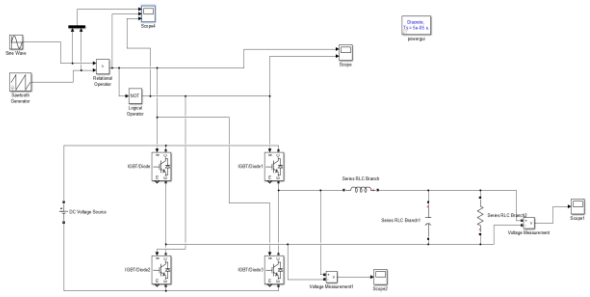


Fig. 7 MATLAB Simulation diagram

The width of the pulses are not identical because the variance of the amplitude of sinewave.

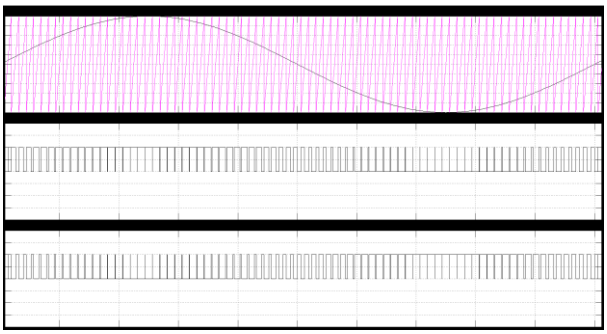


Fig. 8 SPWM pulses

These pulses are given to the switches. In one leg one switch is in conducting and the other switch is in non conducting mode. For every off cycle of output two switches are in conduction mode and they are from different legs of the inverter. And the output voltage of the inverter after connecting LC filter the output is near to sinusoidal with fewer harmonic.

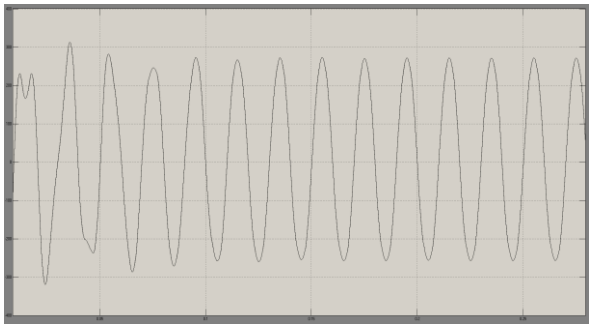


Fig. 9 Inverter ouput voltage

By using matlab simulation we can find Total Harmonic Distortion (THD). It is defined as the ratio of RMS value of all harmonic components to the RMS value of fundamental components. If the THD value is less, then the amount of distortion in voltage is also less.

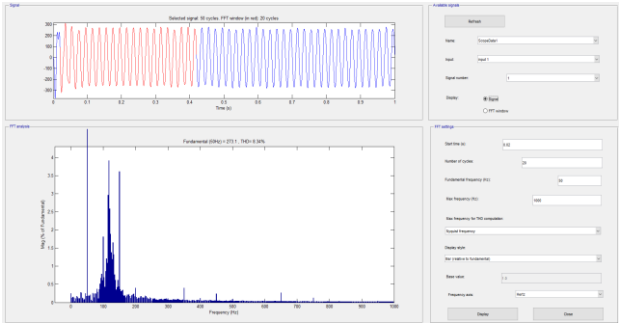


Fig. 10 THD results

V. EXPERIMENTAL RESULTS

A. Figures and Tables

The SPWM pulses are generated with the help of DSP technique by using TMS320F28027 launchpad. The hardware required for SPWM pulses that are laptop, launchpad, XDS100v2 USB cable, software used is code composer studio 6.0, and the O.S used is windows 8.

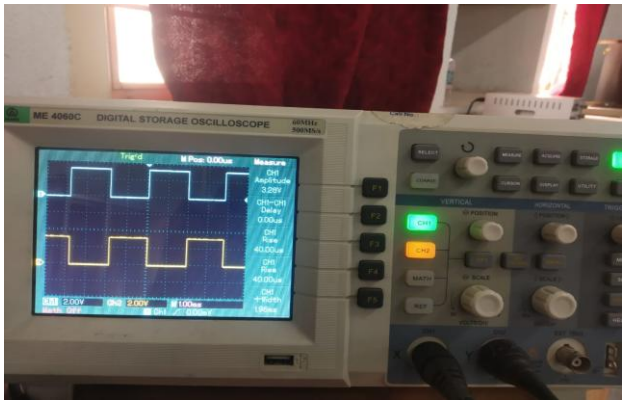
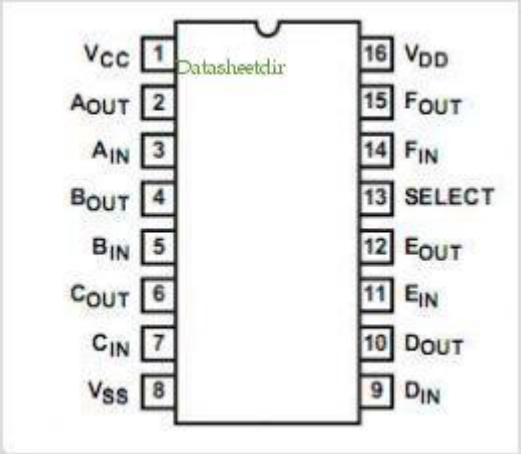


Fig.11 Pulses by using DSP technique

The variance of pulse width duty cycle is tested by using IGBT switch.

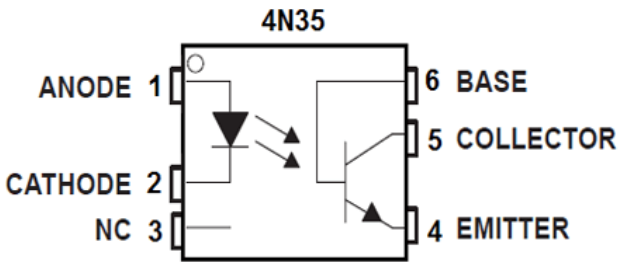
Gate driver is interconnected between microcontroller output signal and the power transistor switch. When a low power is given to a controller IC(gate driver) will convert it to high power. It means that it acts as power amplifier. Its supply voltage is used as input to input gate supply of IGBT, MOSFET switches. Logic circuit is used to generate switching signal for transistor. These output switching signals have few mA of current. The transistor which is turned on by these signals switch ON slowly and they have high power loss. This microcontroller will be over heated due to presence of gate capacitor in the transistor which draws current very fast. Due to overheating it leads to distortion or may damage the chip completely. To avoid this gate driver is placed between microcontroller output signal and the power transistor switches.



CD4504B Type

It is 16 pin chip. It can boost input of 5V to 15V which is sufficient input for Gate supply to IGBT, MOSFET.

To isolate control circuit and power circuit a isolation circuit is placed. Control circuit cannot bare more than 24V where as power circuit operates at 110V or more. For this purpose Optocoupler is used. Optocoupler contains a light as its source, which is usually a infrared light emitting diode (LED). It converts electrical input signal to light, a optical channel which is closed, a photo sensor which detects incoming light and generates electrical energy. Opto isolator can transfer only the light signal. It does not allow the flow of electrical signal. The photo diode, photo resistor, photo transistor can be used as sensors.



The 4N35 opto coupler consists of Gallium arsenide infrared emitting diode which is coupled optically to a monolithic silicon phototransistor detector. It has 100% current transfer ratio. It has applications like general purpose switching circuit, regulation feedback circuits, monitor and detection circuits and solid state relays.

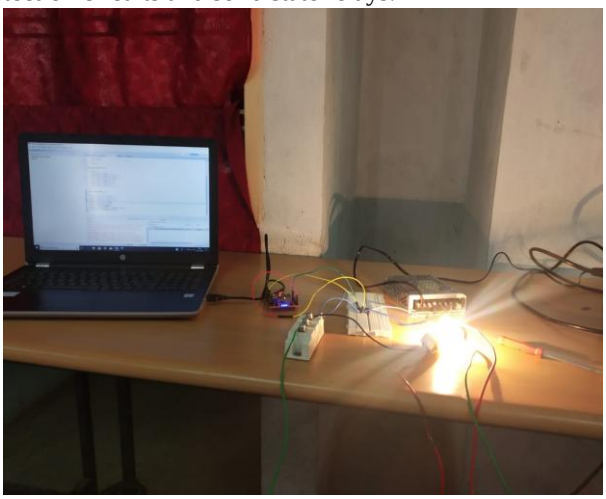


FIG. 12 TESTING OF PULSES

VI. CONCLUSION

The paper deals with DSP based single phase voltage source inverter by using SPWM technique. It gives less THD and sinewave output voltage with low harmonics by using TMS320F28027. And it is done matlab simulink model. This TMS320A28027 piccolo™ microcontroller is C2000 series microcontroller family. By using DSP based SPWM technique we can reduce the lower order harmonics (LOH) and total harmonic distortion (THD) of single phase voltage source inverter. It is used for real time control application and renewable energy sources which are solar, wind etc. This project is done by using resistive load, this can be extended by taking induction motor as load. By this we can control the speed of the single phase induction motor by varying duty cycle of SPWM pulses. By controlling speed this can be used in many applications like Electric Vehicles and Traction.

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