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IMPLEMENTATION OF SPWM TECHNIQUE FOR INVERTER

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Abstract—**Obtaining a pure sinusoidal waveform from the inverter is the major task in the field of electrical engineering. In this paper by implementing the Sinusoidal Pulse Width Modulation (SPWM) technique to obtain sinusoidal output waveform for both single phase and three phase inverter. This paper is mainly developed for the photovoltaic (PV) application. The design is made by the H-bridge topology with the use of MOSFET as a switch. The simulation for the system constructed with the help of MATLAB/SIMULINK. The SPWM method improves the efficiency and reduces the total harmonics distortion in the output voltage.**

Index Terms — **Analog to Digital converter (ADC), H-Bridge, PV Inverter, SPWM Technique.**

I. INTRODUCTION

Now a days the demand for electricity is increasing day by day. One of the best way to satisfy the demand by using of renewable sources of energy [1]. The renewable energy can converted into electrical energy for the house hold applications. The most available form of renewable energy is the solar energy, hence it can be used for all type of domestic appliances, for that the solar inverters most commonly used in this system. The solar inverter should be able to operate the home appliances smoothly. Most of the Uninterrupted Power Supply (UPS) available in market are designed as square wave and quasi wave inverters, which is not suitable for most of the electrical appliances. The outputs of these types of inverters are with more harmonics and are less efficient [2], [3]. If sinusoidal waveform is not provided to the appliances the life time of the appliances will reduce day by day. The generated sinusoidal output waveform from the inverter is to overcome this type of disadvantages. The sinusoidal output waveform can be obtained by implementation of sinusoidal pulse width modulation (SPWM) technique to the inverter circuit. The SPWM technique can be implemented by continuous switching [4]-[8] in a particular sequence of the inverter. The switching technique is characterized by constant amplitude pulse width a different duty cycle of each period. The most common method to implement this technique is to compare the sinusoidal waveform with triangular carrier waveform [9]-[12]. The application of this type of inverter can be for the house hold appliances and high power applications.

An inverter is basically a device, which converts electrical energy of DC form into that of AC form. The DC power can be obtained from battery or PV source and converts it to AC. For example the household inverter receives DC supply 12V or 24V from battery and then inverter converts it to 230V, the AC with a desirable frequency of 50Hz or 60Hz. These DC to AC inverters have been widely used for industrial applications such as UPS, AC motor drives [13]. Recently, the inverters are also playing an important role in various renewable energy applications as these are used for grid connection of wind energy system or photovoltaic system. In addition to this, the control strategies used in the inverters are also similar to those in DC to DC converters. Both current-mode control and voltage-mode control are employed in practical applications.

The DC to AC inverters usually operates on Pulse Width Modulation (PWM) technique. The PWM is a very advance and useful technique in which, the width of the gate pulses are controlled by various mechanisms. PWM inverter is used to keep the output voltage of the inverter at the rated voltage (depending on the user's choice) irrespective of the output load. In a conventional inverter the output voltage changes according to the changes in the load. To nullify this effect of the changing loads, the PWM inverter correct the output voltage by changing the width of the pulses and the output AC depends on the switching frequency and pulse width, which is adjusted according to the value of the load connected at the output so as to provide constant rated output. The inverters usually operate in a PWM and switch between different circuit topologies, which mean that the inverter is a non-linear, specifically piecewise smooth system. In addition to this, the control strategies used in the inverters are also similar to those in DC-DC converters. Both current-mode control and voltage-mode control are employed in practical applications. In the last decade, studies of complex behaviour in switching power converters have gained increasingly more attention from both the academic community and industry [14]-[16]. Various kinds of nonlinear phenomena, such as bifurcation, chaos, border collision and coexisting attractors, have been revealed. Previous work has mainly focused on DC

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power supply systems including DC-DC converters and AC-DC power factor correction (PFC) converters.

II. SINUSOIDAL PULSE WIDTH MODULATION

The Fig.1 shows the SPWM technique for single phase PWM inverter. The SPWM technique is carried out by using two types of waveform, one is reference waveform and the other is carrier waveform. The reference waveform is the sinusoidal waveform with fundamental frequency and the carrier waveform is a triangular waveform with high frequency. The frequency of the carrier waveform is to decide the switching frequency of the inverter. When the frequency of the carrier wave increases the switching frequency also increases. The frequency of the reference waveform determines the inverter output frequency. The output frequency is generated as the compared output of carrier waveform and the reference waveform. The fundamental frequency component of output voltage can be controlled by the modulation index.

$$\mathrm{Ma} = \frac{\mathrm{Vm}}{\mathrm{Vcr}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where Vm and Vcr are the peak value of modulating waveform and carrier waveform. The modulation index is controlled by the peak amplitude it in turns control the rms output voltage of the inverter [17].

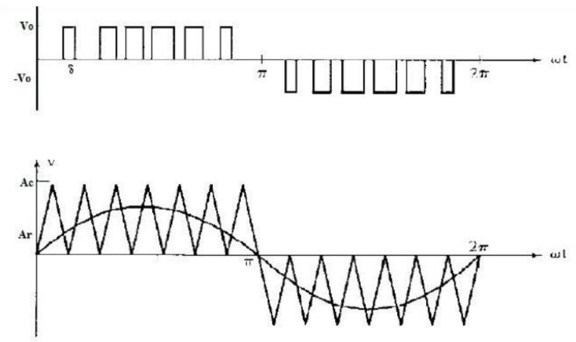

Fig. 1.Sinusoidal pulse width modulation

III. SINGLE PHASE SPWM INVERTER

In order to convert the DC input to AC output, the DC to AC converters are used, which take DC voltage at input and provide AC output voltage and frequency as per desired design specifications to the load. A typical DC to AC converter is known as H-Bridge, which is most commonly used inverter for converting DC to AC. This paper has presented Voltage Source Inverter (VSI) topology to obtain the sine waveform in the output of the inverter. The single phase H-Bridge circuit diagram has been shown in Fig. 2.

The single phase SPWM inverter consists of four switches. Switching has been done in two groups. For generating one cycle two groups are turned ON simultaneously. For generating positive half cycle in the output the switches Q1 and Q4 are turned ON simultaneously the input voltage source V_s appears across the load. For generating negative half cycle in the output the switches Q3 and Q2 are turned ON simultaneously using PWM coming through NOT Gate the voltage across the load is reversed and is $-V_s$ [18]-[20]. The H-Bridge has different operation modes, which are based on quadrant operation; this paper utilized the bipolar technique. In this paper four quadrant drives is implemented. In the Fig 2. If two switches one upper and one lower conduct at the same time such that the output voltage is $\pm V_s$, the switching state is 1 for ON time, where as if these switches are OFF at the same time the switch state is 0.
The rms output voltage can be found from,

$$Vo = \left(\frac{2}{To}\int_{0}^{To/2} Vs^{2}dt\right)^{1/2} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

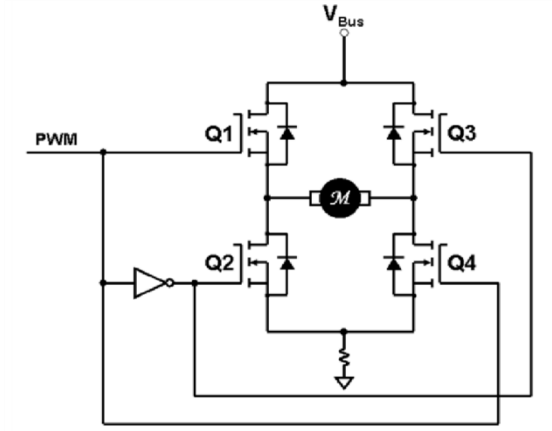

Fig. 2.Single phase H-bridge inverter

Figs 3 represent the simulation model of single phase inverter. The PWM pulses are obtained by comparison of reference waveform and the carrier waveform in the comparator. The signals compared output is generated as a PWM pulse. If the reference waveform is less than that of carrier waveform the comparator output is positive PWM pulses and it is provided to the switches S1 and S2. If the reference waveform is greater than that of carrier waveform the comparator output is negative PWM pulses and it is provided to the switches S3 and S4.

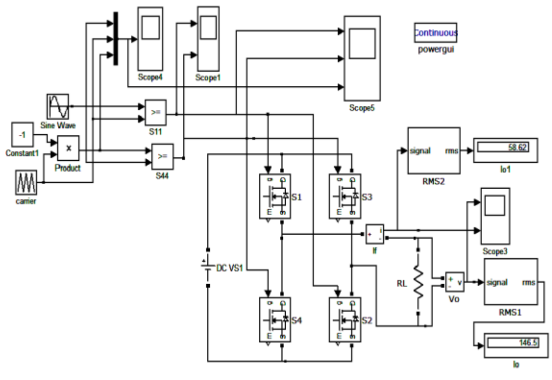

Fig 3.Simulation model for single phase inverter

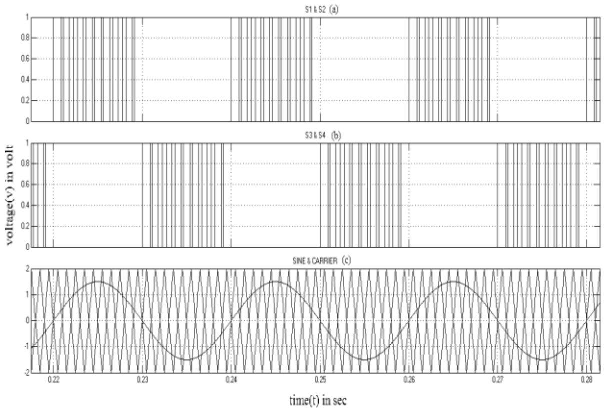

Fig. 4.Switching pulse pattern of the inverter

Fig 4 (a) and Fig 4 (b) represent the switching pulses of the respective switch of the inverter. The switches S1 and S2 pulse represent the positive switching and the switches S3 and S4 pulse represent the negative switching. Fig 4 (c) represent the switching pulses generation and the combination of the reference sinusoidal waveform and triangular carrier waveform. The reference waveform and the carrier waveform are combined together to form a sinusoidal output. The inverter output voltage is controlled by modulation index of the inverter and the pulses from the switching devices are used to generate the sinusoidal output voltage in the inverter. When the inverter output is connected with the R load it will generate the square wave output in the R load. The output voltage and current waveform are shown in Fig.5. In order to obtain the sine waveform in the output to connect the RL load in output terminal. The RL load connected to the inverter, it will filter the unwanted signal and produce us the sinusoidal waveform in the output.

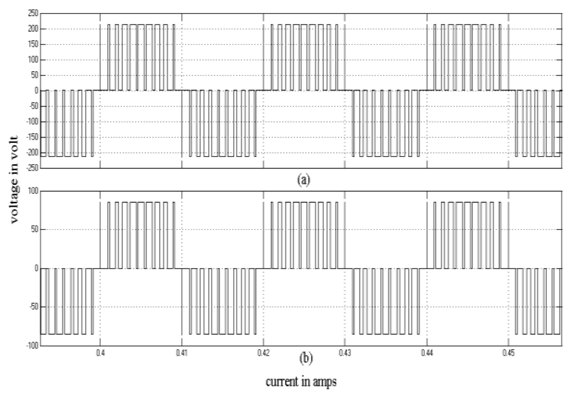

Fig. 5.Output voltage and current waveform

IV. THREE PHASE SPWM INVERTER

The three phase voltage source inverter is shown in Fig. 6. The three phase inverters are generally used for high power applications. The three single phase half bridge inverters are to be connected in parallel to form a three phase voltage source inverter. The inverter is fed by a fixed DC voltage and has three phase-legs each comprising two switches combined with body diode. In the SPWM control, the switches of the inverter are controlled by comparison of a sinusoidal modulating signal with triangular carrier signal. The sinusoidal modulating signal determines the desired fundamental frequency of the inverter output, while the triangular carrier signal decides the switching frequency of the inverter [21]-[23]. The frequency ratio of the triangular carrier signal to the sinusoidal modulating signal is referred to as the modulation frequency ratio.

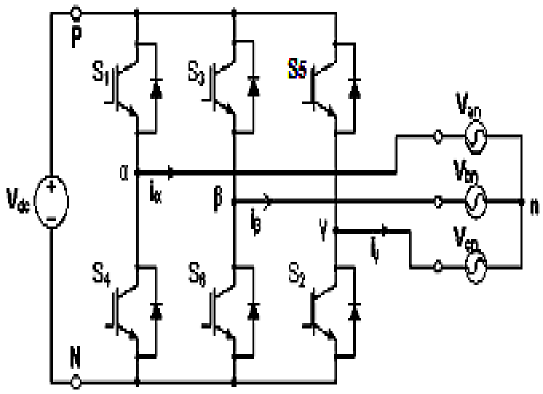

Fig. 6.Three phase SPWM inverter

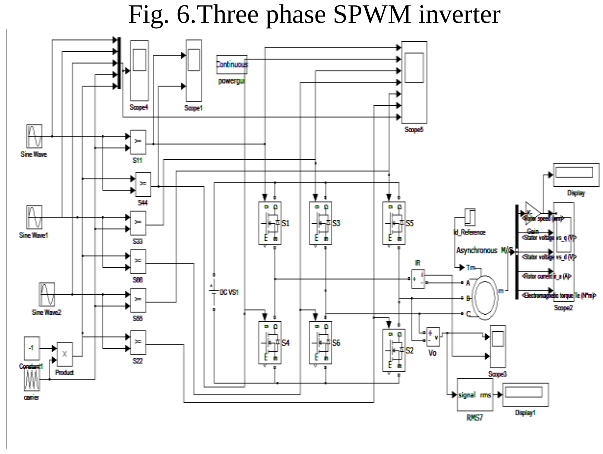

Fig. 7.Simulation model of three phase SPWM inverter

The simulation for three phase inverter is represented in Fig 7. The three phase inverters are designed for the purpose of operating three phase equipment. The three phase design includes three sinusoidal signals at different phase angles, such that is 0^0, 120^0, 240^0. These three sinusoidal waveforms are compared with a positive and a negative carrier waveform to generate positive and negative PWM pulses for the inverter, which should be given to the switching devices. The sinusoidal reference waveforms with triangular carrier waveforms are shown in Fig. 8. The three phase consist of three different positive and negative pulses which should be provided to the three different legs of the switching devices. The switching pulses of all the legs of the switching devices are monitored using a scope, which is given in the Fig. 9. All the switching signals are arranged in such a way that alternate switching of positive and negative signal are provided to each switch at a regular interval of time.

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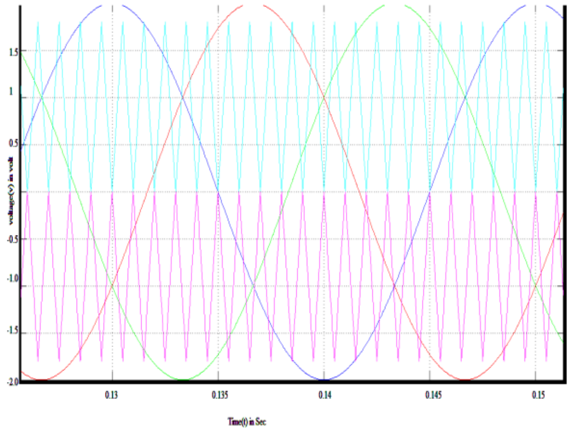

Fig. 8.Sinusoidal reference with triangular carrier

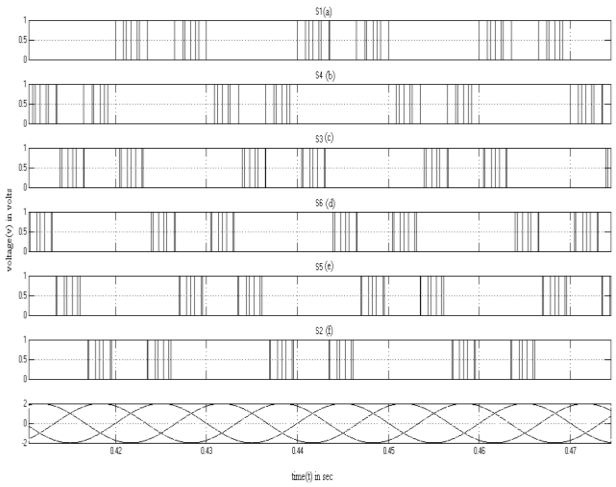

Fig. 9.PWM pulses for three phase inverter

The current and voltage waveforms from the inverter are monitored with a help of an ammeter and voltmeter and the output line voltage and current waveforms are shown in Fig.10. This output line voltage and current waveform are also connected to a scope and the respective waveform is monitored. The output AC current is given to a three phase induction motor and the operating parameters of the motor are monitored continuously in order to identify weather there is a variation of input parameters and the operation of the motor. The output waveforms provided below are the waveforms generated by the MATLAB/SIMULIK software in the designing of the three phase SPWM inverter. Each output waveform is generated at the different stage of the modulation index. .Fig. 11 represent the various types of parameters involved in the operation of the induction motor such as rotor speed, rotor voltage, rotor current stator voltage and also the torque developed in the induction motor.

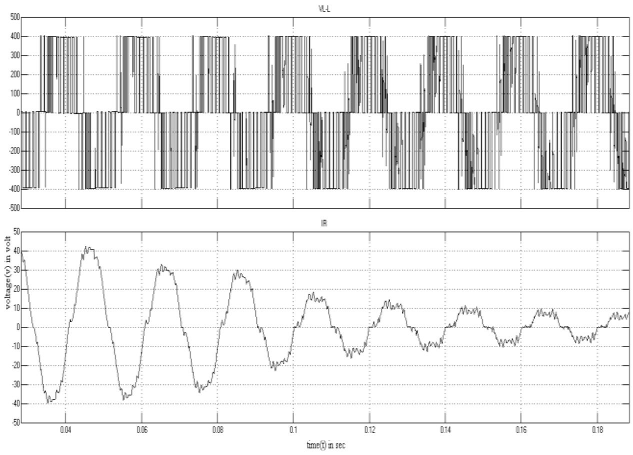

Fig. 10.Output line voltage and current waveform

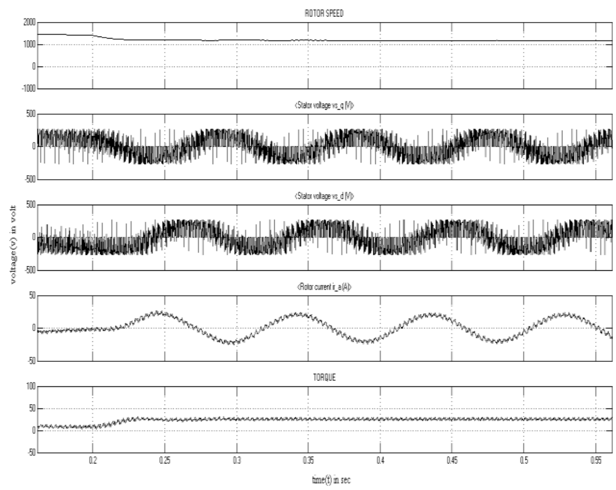

Fig. 11.Induction motor parameters

V. CONCLUSION

A conclusion In this paper single phase and three phase simulation models are developed for voltage source inverter with SPWM technique in MATLAB/SIMULINK. The results of the waveforms for both the simulations have been shown. It was found that the output current and voltage waveforms for single phase and three phase inverter, the output waveform of the inverter were the desired output voltage with expected amplitude and frequency. For the same simulation, the unfiltered voltage and IGBT/Diode current waveforms were of similar nature. These conditions are satisfied in case of using an RL load. The three phase inverter was designed and the output voltage is provided to a three phase induction motor. The operation of three phase induction motor is monitored to identify the variation of frequency and response of the motor towards the sinusoidal wave generated and the output at each of the variations are shown.

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