DESIGN AND DEVELOPMENT OF SINGLE PHASE SPWM INVERTER WITH PROTECTIONS

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ABSTRACT: This paper presents the simulation and hardware design and development of a single phase SPWM inverter with protections. The main work of this configuration is the use of microcontroller to generate sinusoidal pulse width modulation (SPWM) pulses. The essential splendor of this paper an over current and shoot through fault protection scheme for IGBT modules based on the evaluation of fault current level by measuring the voltage between the collector-emitter voltage. The generally used desaturation protection, it provides a fast and reliable detection of fault current. The inverter switching operation are managed with the aidof microcontroller itself. For inverter circuit it is indispensable to set a dead time in order to prevent the short circuits. If any fault happens in inverter circuit the fault sign is transmitted to the controller. The controller resets the protection operation and then fault is recovered. The DSPIC30F2010 microcontroller is able to store all the commands to generate the essential waveform to control the frequency of the inverter through proper design of switching pulses. Subsequently approach and methods and dead time control are discussed. The simulation of the single phase spwm inverter circuit model is simulated in PSIM and MATLAB/SIMULINK SOFTWARE. Finally, simulation results are discussed.

I.INTRODUCTION:

SPWM or sinusoidal pulse width modulation is broadly used in power electronics. The sinusoidal pulse width modulation inverter has been the main function in power electronic, because of its circuit simplicity, low cost and easy to control switching operation. SPWM switching strategies is generally used in industrial applications. SPWM is the frequently used method in motor control and inverter application. SPWM methods are characterized by constant amplitude pulses with different duty cycle for each period. In SPWM approach used to generate switching pulses by means of comparing the triangle wave and sinusoidal wave at desired frequency. To achieve the control system an DSPIC30F2010 microcontroller was used.. The DSPIC30F2010 microcontroller is able to store all the commands to generate the necessary waveform to control the frequency of the inverter through proper design of switching pulses. The IGBT switching operation is controlled by microcontroller unit. The DSPIC30F2010 microcontroller has some features like,It has Modified Harvard Architecture,C compiler optimized instruction set of design,3 external interrupt sources,24-bit wide guidelines, 16-bit wide data way,16 x 16-bit working register.

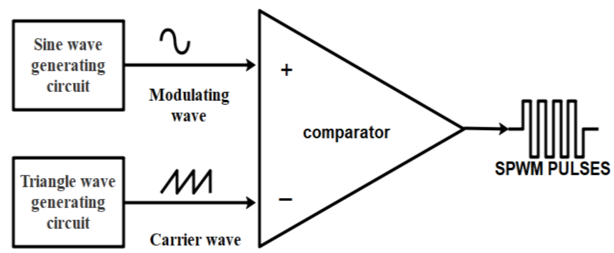

Fig.1 (a) Sinusoidal Pulse Waveform Generation

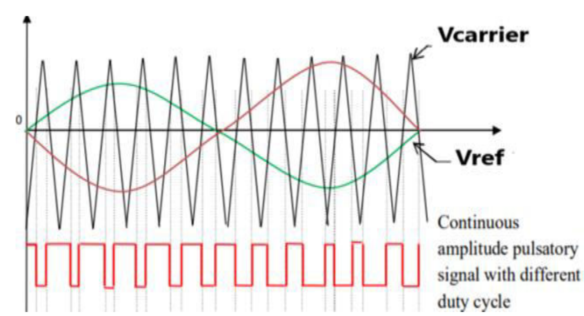

Fig.1 (b) Pulse Waveform

II.PROTECTION METHODS FOR IGBT:

- Shoot Through Fault Protection
- Overcurrent Protection

SHOOT THROUGH AND OVERCURRENT FAULT PROTECTION:

The shoot through fault induced by means of the incorrect turn-on of each IGBTs in one of the inverter legs, which in turn can result from a malfunction in the controller. It could also be caused by wear out/failure of one of the IGBTs in the leg while the healthy IGBT keeps switching.Over current protection detects the abnormal currents in a circuit and prevents them from damaging the circuit.When the overcurrent protector is activated, the inverter stops operating and can be restarted when the cause is removed.

The protection function can be done on the IGBT side. The IGBT failure modes relying upon the following causes like dv\dt increases, dead time to short, malfunction, overheating, thermal runway .when on over current and short circuit fault appear in inverter circuit it may destroy the IGBT module. So it is necessary to design protection circuits. The protection circuit is used to prevent the circuit damage and detects the abnormal current. These types of faults are overcome by way of the use of $V_{CE(SAT)}$ detection method. This approach can protect against all of the short circuit type.TLP5214 is a general-purpose gate drive coupler to which have introduced a Vce(sat) detection function, fault detection function. With the TLP5214 the DESAT pin is used to monitor the voltage (V_{CE}) between the collector and the emitter of the IGBT through the external diode D_{DESAT}. Normally, when the IGBT is in an ON state, V_{CE} will become the saturation voltage. But when an over current happens it enters a non-saturation state and $V_{CE\,(sat)}$ rises. The DESAT pin monitor the voltage between collector and emitter of the IGBT and prevent the over current from damaging the IGBT. If any fault happens in inverter circuit the fault signal is transmitted to the controller. The controller resets the protection operation and then fault is removed. Then using snubber circuit to reduce the inverter switching stress. The capacitance snubber circuits are related between the DC power supply and ground for centralized protection.

III.FULL BRIDGE SINGLE PHASE INVERTER

Now a days the demand for electricity is increasing day by day. An inverter is a device that converts electrical energy of dc power to ac power at desired output voltage. The inverter receives dc supply from source and converts it to ac. Some industrial purposes of inverters are for adjustable speed ac drives, induction heating, UPS (uninterruptible power supplies) for computers, hvdc transmission lines etc. The full bridge single phase inverter consists of the dc voltage source, four IGBT switching elements S1, S2, S3 and S4 and load. The full bridge single phase inverter has two legs, A phase leg and B phase leg. Each leg consists of two power devices connected in series. The load is linked between the midpoints of the two phase legs. Each power control device has a diode connected in antiparallel to it. The diode provide an alternative path for the load current if the power switches are turned OFF.

When the switches S1 and S2 are turned on concurrently for a duration $0 \leq t \leq T1$, the input voltage Vin appears across the load and the current flows from point a to b.S1 – S2 ON, S3 – S4 OFF ==> Vo= Vs.

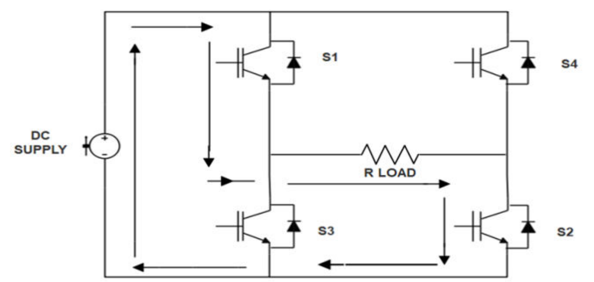

Fig.3 (a) current flow path in Mode 1

When switches S3 and S4 turned on duration $T1 \leq t \leq T2$, the voltage throughout the load the load is reversed and the current through the load flows from point b to a.S1 – S2 OFF, S3 – S4 ON ==> ν o = -Vs

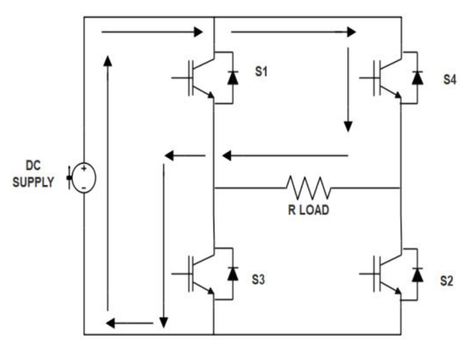

Fig.3 (b) current flow path in Mode 2

IV.ARCHITECTURE OF SINGLE PHASE SPWM INVERTER

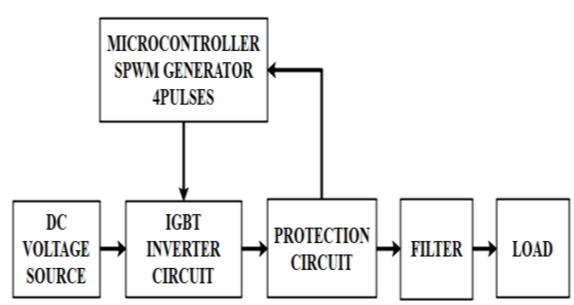

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Fig.4 (a) Block diagram of single phase SPWM inverter with protections

Figure 4(a) is the block layout that describes the hardware development for single phase SPWM inverter circuit. The DC voltage source is given to the inverter circuit. In inverter circuit consists of four IGBT switches and switching operation is controlled by using microcontroller .The arrow shows the SPWM signal flow from DSPIC30F2010 microcontroller through the inverter.

The software development consists designing appropriate switching pulses for inverter circuit with the use of the variable frequency and variable duty cycle SPWM available inside the microcontroller. In microcontroller is desired to manage the inverter with proper switching purposes. The DSPIC30F2010 microcontroller is used to generate the SPWM control signal. The turn on and turn off time of the switches is decide by means of SPWM control signal. The protection function can be done on the IGBT side.

The IGBT failure modes depending upon the following causes like dv\dt increases, dead time to short, malfunction, overheating, thermal runway .when on over current and short circuit fault show up in inverter circuit it may destroy the IGBT module. So it is necessary to design protection circuits. The protection circuit is used to prevent the circuit damage and detects the abnormal current .The inverter circuit has some ripples in output side. This harmonic content are eliminated with the aid of the use of filter circuit. Then filter output is passing to the load circuit.

DEAD TIME CONTROL

One of the most important items to be viewed is the dead time control. There is a possibility of overlapping between ON period switch pair (S1 and S2) and (S3 and S4) pair in full bridge single phase inverter. It is important to avoid the short circuit. The dead time can be manage through programming by using the usage of DSPIC30F2010 microcontroller. Dead time period must be suitable to avoid the problem of damage the switch. If dead time to short it will damage the switch and if dead time to long it will increase the total harmonic distortion.

V.SIMULINK MODEL

The simulation of single phase SPWM inverter in closed loop and open loop system is shown in Fig.5(a) and Fig.5(b) respectively. The simulation of over current and shoot through fault protection shown in Fig.5(c) and Fig.5(d) respectively. The Simulation is carried out in PSIM and MATLAB\SIMULINK software. The single phase SPWM inverter model the use of IGBT and other component models. In single phase SPWM inverter model using resistive load.

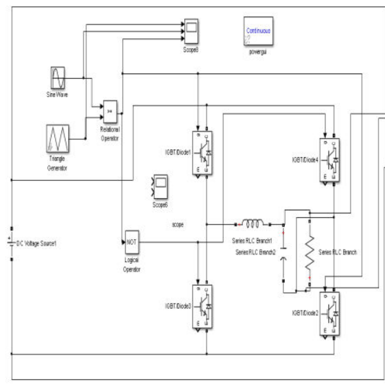

Fig.5 (a) Open Loop Simulation Diagram

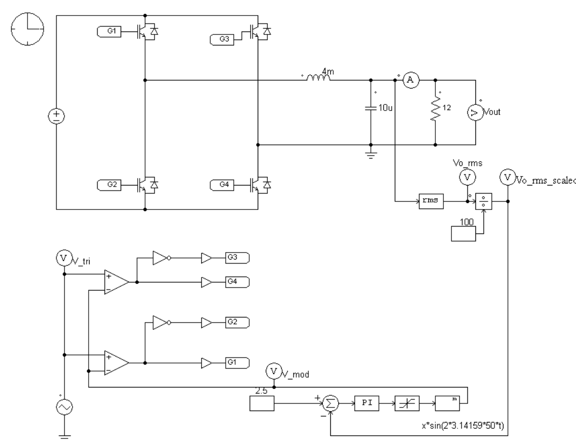

Fig.5 (b) Closed Loop Simulation Diagram

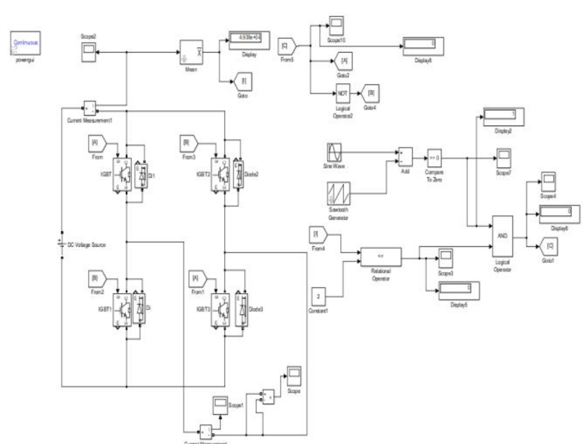

Fig.5(c) single phase SPWM inverter with over current protection

In this figure.5(c) describe about over current protection of single phase SPWM inverter. The simulation of single phase SPWM inverter to control the current level during over current condition. The current measurement device is used to measure the current value in dc source side. In this simulation to set the reference current value. If over current condition occur in output side at the time

these two values are compared to generated the switching pulses. If current value is below the reference value, the switching pulses are generated. If current value is above the reference value the switching pulses are blocked. In this condition the output voltage is zero.

In this figure.5 (d) describe about shoot through fault protection of single phase SPWM inverter. The simulation of single phase SPWM inverter to measure the voltage level during shoot through fault condition. The voltage measurement device is used to measure the collector-emitter voltage level across the switch. In this simulation to set the reference voltage value. If shoot through fault is occur on IGBT inverter side at the time these two values are compared to generated the switching pulses. If voltage value is below the reference value, the switching pulses are generated. If voltage value is above the reference value the switching pulses are blocked. In this condition the output voltage is zero

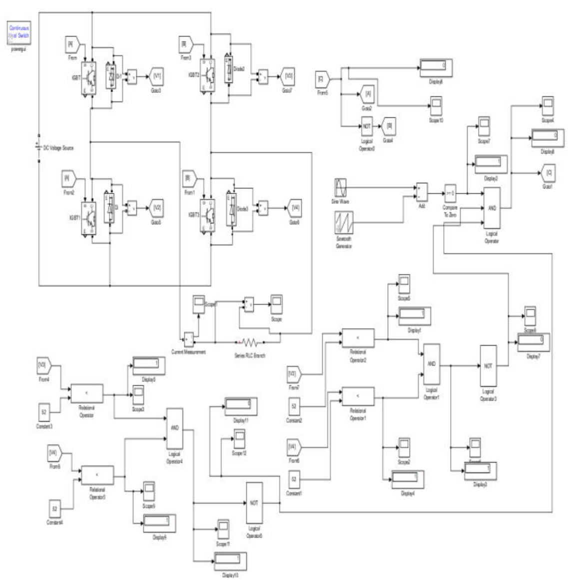

Fig.5(d) single phase SPWM inverter with shoot through fault

VI.RESULT AND DISCUSSION

6.1 SINGLE PHASE SPWM INVERTER IN OPEN LOOP SYSTEM

The circuit components are listed in table I. The simulation of single phase SPWM inverter in open loop device is verified. Here output and input voltage wave form shown in figure.6.1 (a).The input voltage is 30V dc source is given to the inverter circuit and then output voltage is 30V ac source. The open loop system was simulated in MATLAB\SIMULINK software.

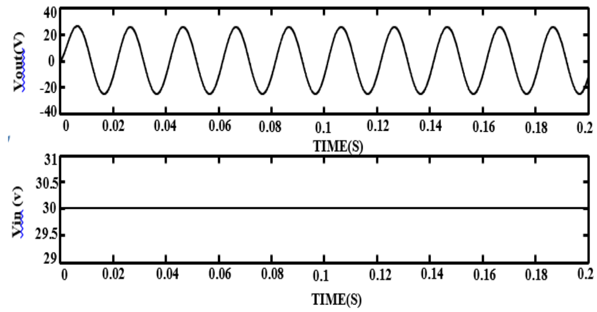

Fig.6.1(a) Input and Output voltage of single phase spwm inverter in open loop system

The pulse waveform shown in figure.6.1(b).This pulses generated by using sinusiodal pulse width modulation method.

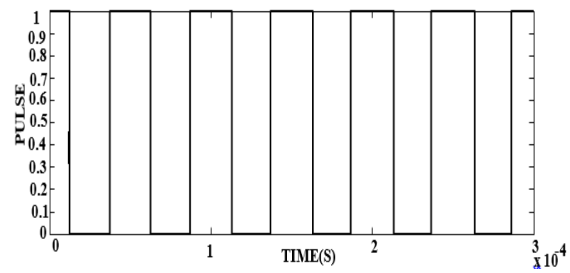

Fig.6.1(b) pulse waveform

TABLE-I CIRCUIT PARAMETERS

SYMBOL	QUANTITY	VALUE
Vin	Input voltage	30V
L	Inductor	200mH
C	Capacitor	1.7683µF
R	Resistor	100ohm
Vo	Output voltage	30V

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6.2 SINGLE PHASE SPWM INVERTER IN CLOSED LOOP SYSTEM

The simulation of single phase spwm inverter in closed loop system is verified. The simulation output results shown in the following figures. The circuit components are listed in table II.Here pulses generated by sinusoidal pulse width modulation technique . In spwm method used to generating the pulses by means of comparing triangular and sinusoidal waveform. The modulating signal waveform and triangular waveform shown in fig.6.2(a) and fig6.2(b) respectively. The sine and triangular comparision waveform shown in fig.6.2(c).

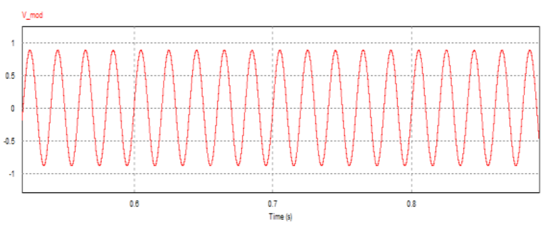

Fig.6.2(a) modulating singal waveform

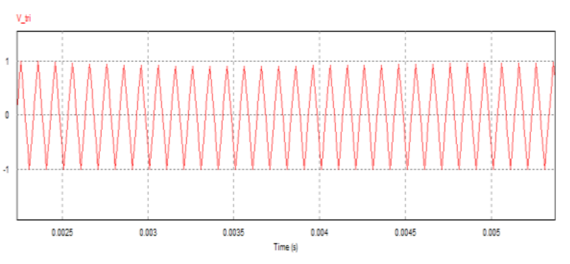

Fig.6.2(b) Triangular waveform

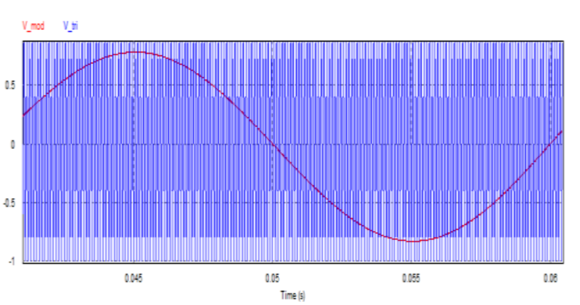

Fig.6.2(c) Sine and Triangular Wave Comparison

The switching pulse waveform shown in figure 6.2(d). This figure described about switching pulses during on and off condition.

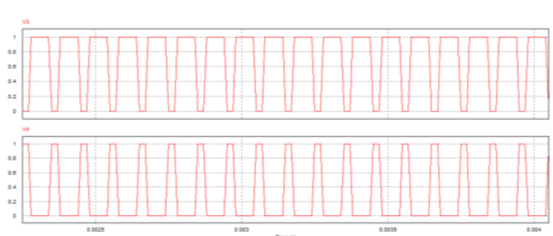

Fig.6.2 (d) switching pulse waveform(On-off condition)

The pulse waveform for S1, S2, S3, S4 pluses shown in figure.6.2 (e). The S1, S2, S3, S4 switching pulse waveform are consists of V_1, V12, V13, V2. The V1 and V13 are on condition and V2 and V12 are off condition switching pulses.

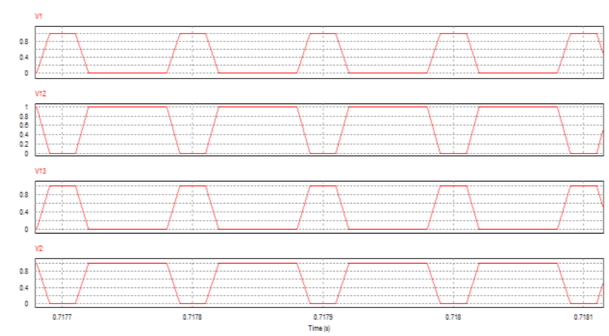

Fig.6.2 (e) pulse waveform for S1, S2, S3, S4

This is output voltage and current waveform of single phase SPWM inverter with filter shown in the figure 6.2 (f). The inverter input is 100V dc source and then output is 250vV ac source. Filter circuit is used to reduce the harmonic.

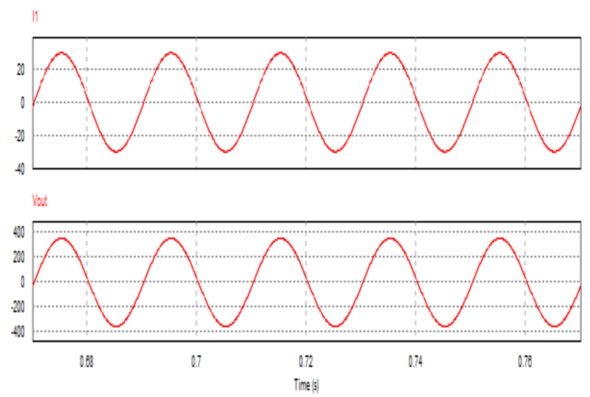

Fig.6.2 (f) output voltage and current waveform of single phase SPWM inverter with filter

During short circuit condition the output volatge and current waveform of single phase SPWM inverter shown in the figure6.2 (g). when shoot through fault occur in inverter circuit the switch S1 and S2 is ON condition and S3 and S4 is off condition.In this condition caused by incorrect turn on of IGBTs is one of the inverter leg.so short circuit condition the inverter output not sinusoidal because it has some harmonics.

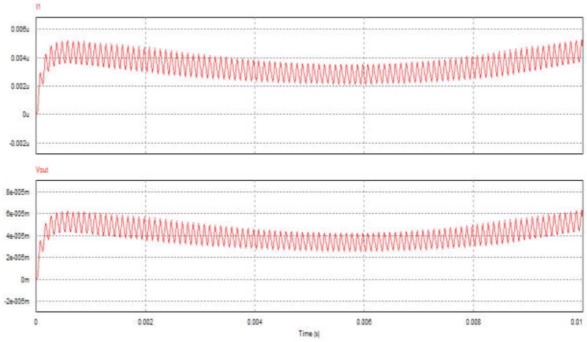

Fig.6.2 (g) Output voltage and current waveform of single phase SPWM inverter in short circuit condition.

The sine and triangular wave comparison waveform during short circuit condition shown in figure 6.2(h).The comparator is used to compare the reference and modulation signal and produce the switching pluses.

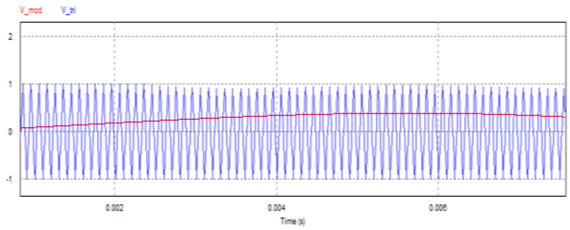

Figure 6.2 (h) sine and triangular wave comparison during short circuit condition

when shoot through fault occur in inverter circuit the switch S1 and S2 is ON condition and S3 and S4 is off condition.In this condition caused by incorrect turn on of IGBTs is one of the inverter leg. The switching pluses waveform during short circuit condition shown in figure 6.2 (i).V1 and V7 are one of the inverter leg.V2 and V5 is the one of the inverter leg. During short circuit condition period V1 and V7 are ON condition and then, V2 and V5 are OFF condition.The switching cycle(on-off condition) waveform shown in figure 6.2 (j).

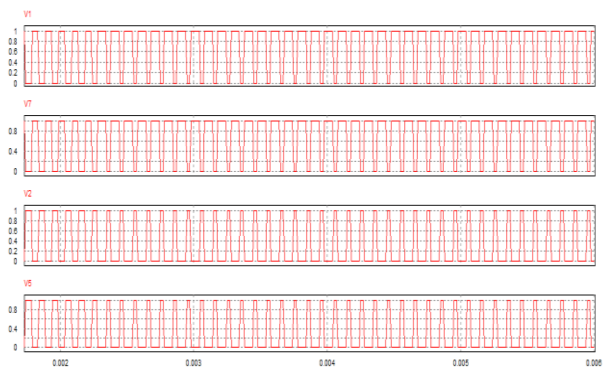

Fig.6 (i) switching pulse waveform during short circuit condition

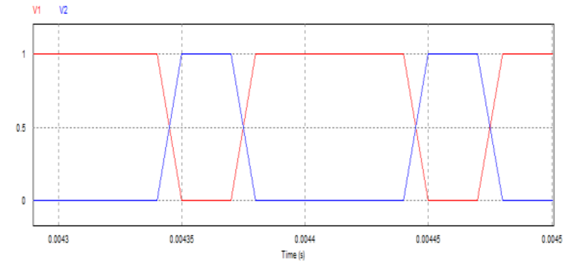

Fig.6 (j) switching cycle (on-off condition)

TABLE-II CIRCUIT PARAMETER

SYMBOL	QUANTITY	VALUE
Vin	**Input voltage**	**100V**
L	**Inductor**	**4mH**
C	**Capacitor**	**10µF**
Vo	**Output voltage**	**250V**
R	**Resistor**	**12ohm**

6.3 SINGLE PHASE SPWM INVERTER WITH OVERCURRENT PROTECTION

The simulation of single phase spwm inverter with overcurrent protectionis verified. The simulation output results shown in the following figures.Here pulses generated by sinusoidal pulse width modulation technique.The output voltage and output pulse waveform shown in Fig.6.3 (a) and Fig.6.3(b).

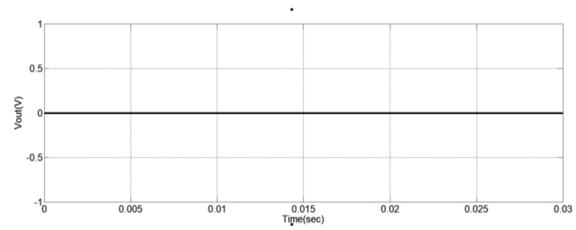

Fig.6.3 (a) output voltage waveform of single phase SPWM inverter with over current protection

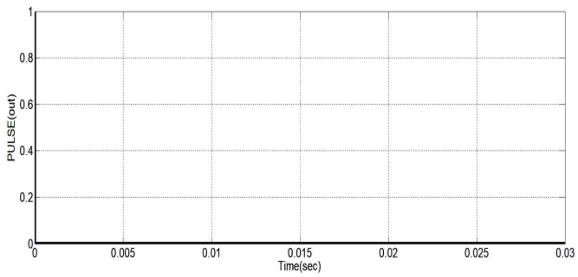

Fig. 6.3 (b) output pulse waveform of single phase SPWM inverter with over current fault protection

6.4 SINGLE PHASE SPWM INVERTER WITH SHOOT THROUGH FAULT PROTECTION

The simulation of single phase spwm inverter with shoot through fault protectionis verified. The simulation output results shown in the following figures.Here pulses generated by sinusoidal pulse width modulation technique.The output voltage and output pulse waveform shown in Fig.6.4(a) and Fig.6.4(b) respectively.

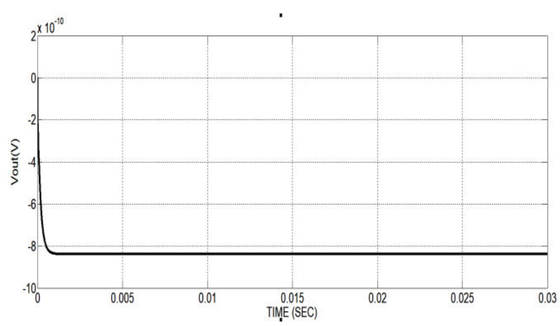

Fig.6.4 (a) output voltage waveform of single phase SPWM inverter with shoot through fault protection

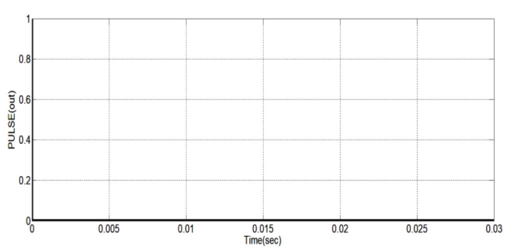

Fig. 6.4 (b) output pulse waveform of single phase SPWM inverter with shoot through fault protection

Simulation of the single phase SPWM inverter device model is simulated in PSIM Simulink software. Both simulation results are verified.

VII.CONCLUSION

An over current and shoot through fault protection scheme is presented which could protect an IGBT module against overload and short circuit condition. This proposed circuit provides a fast and reliable detection of IGBT fault current. The presented inverter has some advantages such as, simple and low cost. The major work is to develop the control circuit for single phase SPWM inverter using DSPIC30F2010 microcontroller. The SPWM technique used to control the inverter switches therefore the inverter control circuit hardware is reduced. The Simulation of the single phase SPWM inverter device model is simulated in PSIM Simulink software. Both simulation results are verified.

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