PF and THD Measurement for Power Electronic Converter

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Abstract- This paper describes the measurement of power factor and total harmonic distortion based on different pulse width modulation techniques. Problem statement: The converters system generates discrete output waveforms which require large inductances connected in series with the respective load to generate the desired current waveform. Mostly, output waveforms are unexpected and it produces harmonic contamination, high frequency noise, and additional power losses. In power electronic convertor system uses different switching technique with single phase invertor. This includes single pulse width modulation and multiple pulse width modulation. These pulse width modulation techniques produce distortion factor and high amount of harmonic content in the output. Harmonic content should be low for better performance in the power electronic convertor. Approach: For avoiding the problem in existing system, we used sinusoidal pulse width modulation with different switching techniques for reduction of distortion and harmonic content in the output waveform without decreasing the inverter power output. If the level of the inverter will be increased, the numbers of components are increased. So, the switching stress will be increased. In that carrier based PWM schemes, the In phase Disposition method is good compared to other method. Results and Conclusion: The results of our experiment indicate that the content of THD is reduced by using SPWM with multi carrier switching technique in multilevel inverter. Unwanted operating characteristics associated with PWM converters can be overcome with multi-level converters, with the addition that higher voltage levels can be achieved The MATLAB Simulink environment is used to simulate the results.

Index Terms - Total harmonic distortion (THD), Power factor (PF), Sinusoidal pulse width modulation (SPWM), Unipolar, Bipolar, Phase disposition techniques.

1. INTRODUCTION

Power electronics devices contribute important part of harmonics in all kind of applications, such as static var compensators (SVC), power rectifiers, and thyristor converters. The inverter converts dc power to ac power at desired output voltage and frequency. The dc power input to the inverter is obtained from an existing power supply network or from any other source [1]. Inverter is an adjustable-frequency voltage source because filter capacitor across the input terminals of the inverter provide a constant dc link voltage. According to the source inverters can be broadly classified into two types are as follows:

- Voltage source inverters
- Current source inverters

Generally a voltage–source inverter is one in which the dc source has small or negligible impedance. The voltage at the input terminals is constant. A current –source inverter is fed with adjustable current from the dc source of high impedance that is from a constant dc source.

A voltage source inverter employing thyristor as switches, some type of forced commutation is required, while the VSIs made up of using GTOs, power transistors, power MOSFETs or IGBTs, self-commutation with base or gate drive signals for their controlled turn-on and turn-off. A standard single-phase voltage or current source inverter are in the half bridge or full bridge configuration. The single-phase units can be joined to have three-phase multiphase topologies. Some industrial applications of inverters are for adjustable-speed ac drives, induction heating, standby aircraft power supplies, UPS (uninterruptible power supplies) for computers etc.

According to the type of output supply required can be broadly classified into two types are as follows:

- Single phase inverter
- Three phase inverters

Based on types of switches they are classified as a forced commuted inverter and self-commuted inverter. Based on view point they are classified as a series inverter and parallel inverter. Bridge inverter classified as a half bridge inverter and full bridge inverter.

Multi-level inverters have emerged recently as very important role in the area of high power and medium voltage applications [2]. The multilevel inverters are,

- Diode clamped multilevel inverters

- Flying capacitor multilevel inverter
- Cascaded H-bridge multilevel inverter

An inverter is device which converts DC power into AC power at desired output voltage and frequency can be varied as per the requirement of load. Inverters are used in industrial and much other application. This paper describes the working of voltage source single phase half bridge inverter, full bridge inverter and multilevel inverter with different switching techniques.

1.1 Single Phase Voltage Source Half Bridge Inverter

It includes two semiconductor power switches S1and S2. These switches are used as a BJT, IGBT etc. It consists of anti-parallel diode D1and D2. These diodes are called as feedback diode. Diode D1 and D2 provide the freewheeling operations and they are needed only if load is inductive and capacitive. For pure resistive load both diode are not in working condition. It consists of two switches operate alternatively.

In resistive load current waveform follows the voltage waveform therefore power factor of the circuit becomes unity, but in the case of capacitive load and inductive load the voltage and current waveforms leading or lagging with respect to each other therefore power factor of the circuit is not constant.

1.2 Single Phase Voltage Source Full Bridge Inverter

A single phase full bridge inverter consists of two arms. First arm consist of two switches S1, S3 and second arm consist of two switches S2 and S4. This type of inverter is used for high power application. The switches in each arm of inverter are operating alternatively. If switches in both arm having same mode (On/Off) then it will be damage. In practice these switches are OFF for short period of time, that time is called as blanking time. Blanking time is used to avoid the condition of short circuit which is produce in the circuit. In order to prevent the condition of short circuit dead time mechanism is used.

The Working of single phase full bridge inverter divided into two conditions. In one half cycles, switch S1 and S4 are turned on at that time switch S2 and S3 are turned off. For the second half cycle S2 and S3 is turned on at the same time S1 and S4 turn off. In such way all the switches are not turned on simultaneously. The output voltage of the inverter will change alternately from positive half period and negative half period.

1.3 Single Phase Voltage Source Multilevel Inverter

Multilevel inverter is available in different structure. There are two full bridge circuit are used in this inverter and they are cascaded with separate DC source. DC sources are obtained from renewable energy sources. DC sources are easily interfaced with multilevel inverter for high power application.

This type of inverter does not need clamping diode. It increases the voltage level. It synthesizes waveforms with better harmonic spectrum and low switching frequency hence it is used in high power inversion.

2. METHODOLOGIES

Pulse width modulation technique is the generation of constant amplitude pulse by modulating the pulse duration or width of carrier by using modulating signal. Each technique produced different output. Basic PWM techniques are as follows:

(1) Single Pulse Width Modulation
(2) Multiple Pulse Width Modulation
(3) Sinusoidal Pulse Width Modulation

2.1 Single Pulse Width Modulation

In this modulation there is an only one output pulse per half cycle. Output signal is obtained by comparing rectangular reference signal with a triangular reference signal. The output pulse width can be varying from 0 to 100 percent of duty cycle. The frequency of both signals is same.

2.2 Multiple Pulse Width Modulation

It is also called as uniform pulse width modulation. In single pulse width modulation large amount of harmonic contents are produced. Output voltage level is also reduced. These harmonic contents can be reduced by having the many pulse in each half cycle and all pulses are of equal width. The carrier signal is a triangular wave having frequency of fc. The frequency fc of triangular wave determines the number of pulses per half cycle.

2.3 Sinusoidal Pulse Width Modulation

The carrier signal and reference signal is mixed in comparator. Output pulse is generated at the output of comparator circuit. When magnitude of reference signal is more than carrier signal, the output of comparator is high. It is observed that width of the out pulses is not same. The width of pulse depends on the angular position of pulse. By varying the modulation index we can vary the RMS value of output voltage. The distortion factor and lower order harmonic get reduced [3, 4].

3. SWITCHING TECHNIQUES

Following are different switching technique which is used in the half bridge inverter, full bridge inverter and multilevel inverter circuit.

(1) PWM with bipolar voltage switching
(2) PWM with unipolar voltage switching
(3) PWM with multicarrier switching

3.1 SPWM with Bipolar Switching Technique

Figure.1 consists of comparator circuit which is used to compare the reference voltage waveform (Vr) with the triangular carrier signal (Vc). The Output of the comparator is bipolar switching signal. If this scheme is applied to full bridge single phase inverter, then all switches S1, S2, S3 and S4 are turned on and off simultaneously.

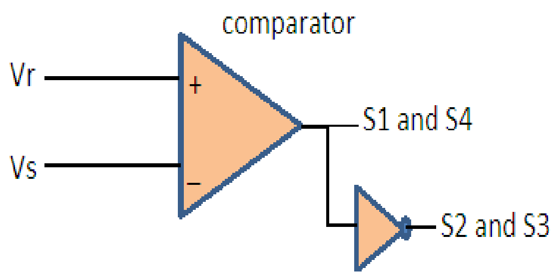

Fig.1: Bipolar PWM generator

3.2 SPWM with Unipolar Switching Technique

Figure.2 indicates the process of comparing these two signals to produce the unipolar voltage hence it is called as unipolar switching technique. In this case, the triangular carrier waveform is compared with two reference signals which are positive and negative signal. Comparators are used between the reference waveform (Vr) and inverse reference waveform (−Vr). The effective switching frequency is seen when the load is doubled and the voltage pulse amplitude is half.

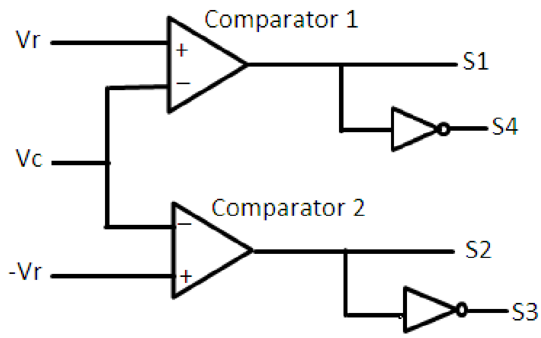

Fig.2: Unipolar PWM generator

The output voltage switches between 0 and Vdc or between 0 and –Vdc. Because of this, the harmonic content of the output voltage waveform is reduced as compared to bipolar switching technique. The amplitude of the harmonics and its sidebands is much lower for all modulation indexes thus making filtering easier. The harmonic is reduced by changing the modulation index.

3.3 SPWM with multicarrier switching technique

Generally the carrier base PWM schemes are classified into two types, they are (i) Phase shifted multi carrier modulation and (ii) Level shifted multi carrier modulation. Then the level shifted multi carrier modulation schemes further classified into three subtype, they are (i)phase disposition method (ii)Alternative phase opposite disposition method and (iii)Phase opposite disposition method. Now we discuss phase disposition method used in multilevel invertor [4, 5].

In this multi carrier switching technique, the two reference signals in unipolar technique are replaced with two carrier signal and the one triangular signal in unipolar technique is replaced by reference sinusoidal signal. When producing nth number of output level, N-1 of triangular carrier will be needed to be compared to the only sinusoidal signal. This method is used in 5-level inverter due to this; harmonic distortion is much more reduced as compared to unipolar switching technique which is used in the full bridge inverter circuit. In phase disposition technique, a zero point is set as a reference point. The carrier signals are set to be in-phase for above and below the reference point (zero line).

4. MATLAB SIMULATION

This paper involves the simulation of power electronic inverter circuit using SPWM in MATLAB Simulink by using different switching technique. Perform the analysis of total harmonic distortion (THD) by using the FFT analysis and measurement of power factor (PF) is take place. Using SPWM and analyze the performance of THD and PF for single phase half bridge inverter circuit using the bipolar switching technique, single phase full bridge inverter circuit by using the using the phase disposition technique.

We also perform FFT analysis for all models using power GUI module. We can also configure the parameter with the help of power GUI module.

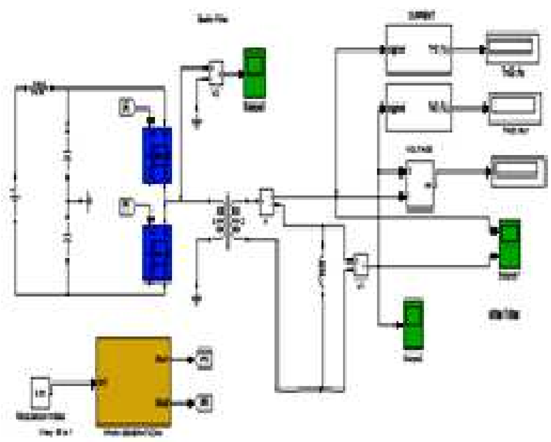

Fig.3: Simulation circuit for half bridge inverter.

Figure.3 shows the modeling of half bridge inverter into MATLAB Simulink. The switching elements used in the circuit are power MOSFET.

There is no need for anti-parallel diode. It consists of two MOSFET, M1 and M2 semiconductor power switches having the parameter of 0.1 FET resistance and initial diode resistance of 0.01Ω. This is controlled by SPWM model. When M1 is turned on for the period of 0 to T/2, then instantaneous output voltage across the load is Vdc/2 at that time M2 is in off state. When M2 is turned on for the period of T/2 to T, instantaneous output voltage will appear equal to –Vdc/2.

By changing the modulation index from SPWM block, this block is design for the generation of SPWM signal which are used as gating signal for power switching elements. Different value of modulation index produces different output values of PF, THD.

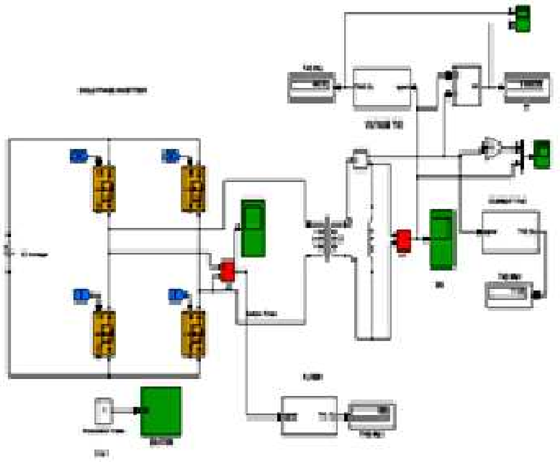

Fig.4: Simulation circuit for full bridge inverter

Figure.4 shows the modeling of full bridge inverter into MATLAB Simulink. It consists of the two arms each arm consists of the two MOSFET having the FET resistance is 0.1 and initial diode resistance of 0.01Ω. In first arm consists of MOSFET M1 and M3 and second arm consists of MOSFET M2 and M4 as semiconductor power switching elements. When M1 and M4 kept on for the one half period at the same time M2 and M3 is in off state, then output voltage equal to the Vdc. When M2 and M3 kept on for the next half period at the same time M1 and M4 is in off state, then output voltage equal to the –Vdc/2.

This model uses the transformer in the output stage therefore the output voltage is increased up to desired level. THD is the measurement for different load and measurement of power factor is take place for different load value. Figure.5 shows the modeling of the multilevel inverter into MATLAB Simulink. It consists of two full bridge inverter circuits are cascaded with different DC sources. It consists of the 8 MOSFET switches, which is controlled with the help of SPWM model by using the phase disposition technique. This SPWM model are designed to generate the SPWM pulses, these pulses act as the gating pulses for the power switching element used in the multilevel inverter. Phase disposition technique is multicarrier switching technique. Multilevel inverter is used as a five level inverter therefore the four carrier signals with respect to one reference signal are used in the SPWM generation [6]. All the above simulation circuit is tested for different values of load by changing the different modulation index as well as different modulation technique, for comparative analysis of distortion factor and PF. comparative analysis of distortion factor and PF is depend upon different value of resistive load.

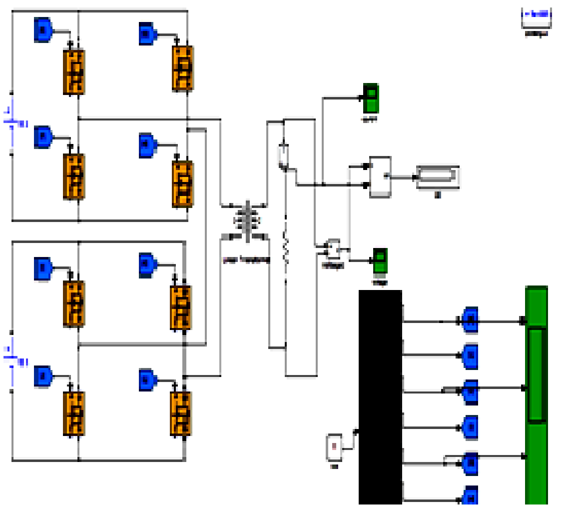

Fig.5: Simulation circuit for multilevel inverter

Here we discuss the simulation result for the resistive load when value of resistive load is equal to the 1000Ω only. Figure.6 shows that by using FFT analysis THD is equal to 17.82% for the half bridge inverter when the load R is equal to 1000Ω.

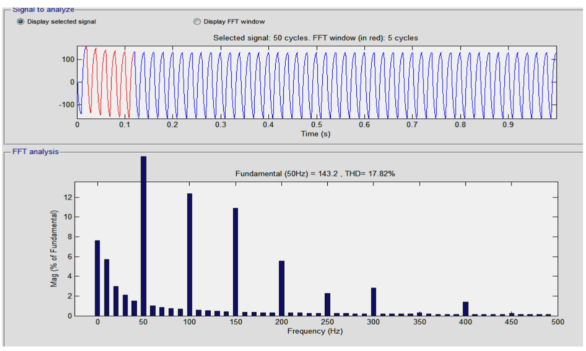

Fig.6: THD measurement for half bridge inverter.

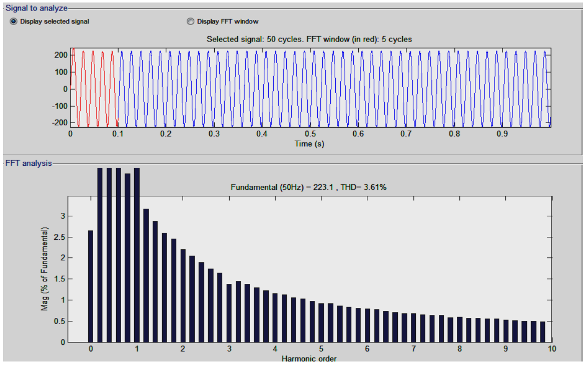

Fig.7: THD measurement for full bridge Inverter.

Figure.7 shows that by using FFT analysis THD is equal to 3.61% for full bridge inverter when the load R equal to 1000Ω. Figure.8 shows that by using the FFT analysis THD equal to 1.70% for multilevel inverter when the load R is equal to 1000Ω.

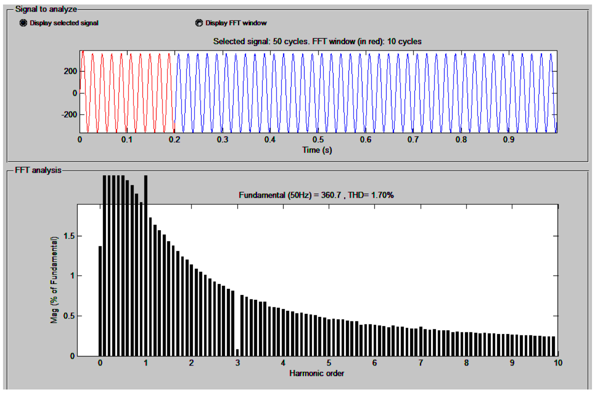

Fig.8: THD measurement for multilevel inverter.

It is observed that based on different values of resistive load (R), the THD is less for the multilevel inverter as compared to the single phase full bridge inverter and single phase half bridge inverter and PF is unity. In resistive load voltage and current waveforms are in phase, so phase angle is not form and the value of PF is at unity.

Table 1: For R load R=1000Ω

Modu-lation index (M)	Half bridge inverter THD%	Full bridge inverter THD%	Multilevel inverter THD%	PF
0.5	24.24	3.69	1.73	1
0.8	19.17	3.63	1.71	1
1	17.82	3.61	1.70	1

Table.1 shows the readings of THD and PF for the resistive load when R is equal to the1000Ω for different modulation index. Graphical representation is shown in Figure 9.

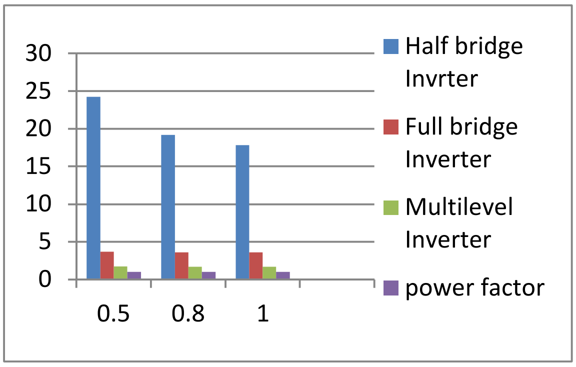

Fig.9: Modulation index vs % total harmonic distortion for different inverter.

In different types of inverter circuit not only to measure the THD but also check the PF for different circuit. Instead of R load we are taking reading for R-L load. Similarly, we discussed the simulation result for the load when R is 1000Ω and L is 50mh only when the modulation index is unity.

Table 2: For RL Load M=1

Load	Half bridge inverter THD%	Full bridge inverter THD%	Multilevel inverter THD%	PF
500Ω, 500mh	21.63	16.75	3.52	0.95
800 Ω, 500mh	19.52	12.10	2.70	0.98
1000 Ω, 500mh	19.42	10.55	2.41	0.98

Table.2 shows the readings of THD and PF for different values of R-L load when modulation index is equal to unity Graphical representation is shown in Figure 10.

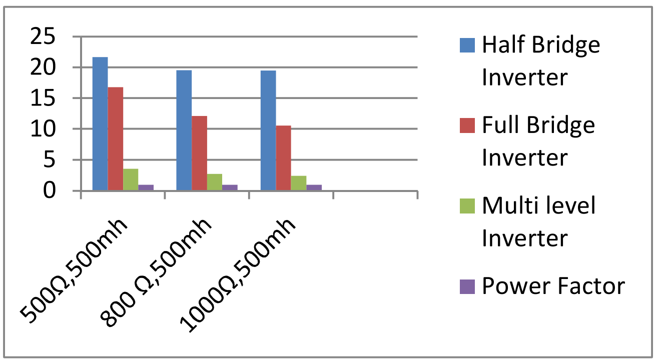

Fig.10: R-L load vs % total harmonic distortion for different inverter circuit.

5. CONCLUSION

Power converter system using different inverter was designed and implemented. It was tested with different parameter. This study represents analysis of single phase SPWM with different inverter circuit for calculation of THD and PF for different inverter circuit. It is observed that for the resistive load, minimum THD is obtained for multilevel inverter by using phase disposition technique as compared to single phase half bridge and full bridge inverter and power factor unity is obtained. We also observed that for the R-L load, minimum THD is obtained for multilevel inverter by using phase disposition technique as compared to single phase half bridge and full bridge inverter and power factor is change at each instant. This simulation results are tested using MATLAB Simulink power system.

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