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MICROCONTROLLER IMPLEMENTATION OF SINGLE PHASE INVERTER SWITCHING STRATEGIES

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Abstract

This paper presents the practical microcontroller implementation of single phase inverter switching strategies. The attractiveness of this configuration is the used of a microcontroller to generate sinusoidal pulse width modulation (SPWM) pulses. The difference amplitude modulation ratio m_a starting from 0.3 until over modulation with 2 KHz switching frequency was implemented and tested. Selected results from the experimental prototype will be presented. The result shows the relationship between amplitude modulation ratio with total harmonic distortion (THD) and dead time period.

1. Introduction

SPWM or sinusoidal pulse width modulation is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches. The pulse width modulation inverter has been the main choice in power electronic for decades, because of its circuit simplicity and rugged control scheme [1]. SPWM switching technique is commonly used in industrial applications. SPWM techniques are characterized by constant amplitude pulses with different duty cycle for each period. The width of this pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content [2]. Sinusoidal pulse width modulation or SPWM is the mostly used method in motor control and inverter application. In this development a unipolar SPWM voltage modulation type [3]-[4] is selected because this method offers the advantage of effectively doubling the switching frequency of the inverter voltage, thus making the output filter smaller, cheaper and easier to implement. Conventionally, to generate this signal, triangle wave as a carrier signal is compared with the sinusoidal wave, whose frequency is the desired frequency.

The proposed alternative approach is to replace the conventional method with the use of microcontroller. The use of the microcontroller brings the flexibility to change the real-time control algorithms without further changes in hardware. It is also need low cost and has a small size of control circuit for the single phase bridge inverter.

To achieve the control system an Atmel AT89C2051-24PI microcontroller was used. The atmel AT89C2051-24PI is a low voltage, high performance CMOS 8-bit microcomputer with 2K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high density nonvolatile memory technology and is compatible with the industry standard MCS-51 instruction set. It also has two 16-bit timers that deliver the function use in this application. By combining a versatile 8 bit CPU with Flash on a monolithic chip, the Atmel AT89C2051 is powerful microcomputer with provides a highly flexible and cost effective solution to many embedded control applications.

2. Pulse Width Modulation Control

The frequency modulation ratio *mf* is defined as the ratio of the frequencies of the carrier and the reference signals which is written as

$$mf = \frac{f_{carrier}}{f_{reference}} = \frac{f_{tri}}{f_{\sin}} \qquad (1)$$

The amplitude modulation ratio m_a is define as the ratio of the amplitude of the reference and carrier signals and is given by

$$m_a = \frac{V_{m,\,reference}}{V_{m,\,carrier}} = \frac{V_{m,\,\sin}}{V_{m,\,carrier}} \qquad (2)$$

The amplitude of the PWM of the fundamental frequency output is controlled by m_a. This is significant for an unregulated DC voltage because the value of m_a can be adjusted to compensate the variations in the DC voltage, thus producing a constant amplitude output. If m_a is greater than 1 or over modulation, the amplitude of the output increases with m_a, but not linearly.

3. Approach and Method

Figure 1 below show the full bridge single phase inverter and its switching strategy.

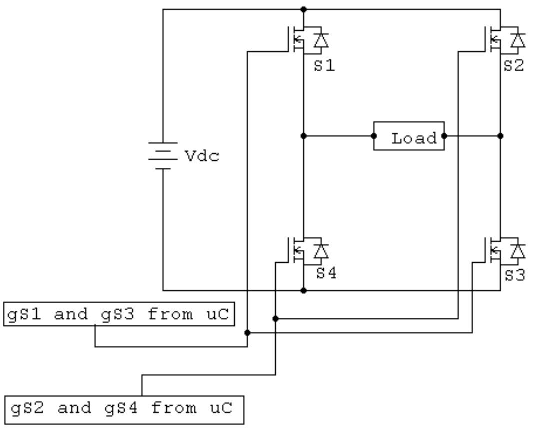

Figure 1: Single phase full bridge inverter

Figure 2 shows the strategy control of the switching technique for the inverter. The gS1, gS2, gS3 and gS4 are output gating signal for power switchers S1, S2, S3 and S4 respectively. Figure 2a shows the comparing signal between carrier signal and reference signal. While figure 2b shows the pulse for the power switchers and figure 2c shows the output of the inverter. In this development every pulses for gS1, gS2, gS3 and gS4 was programmed by using microcontroller. The size of the pulses is depended on the comparison between carrier signal and reference signal. When the amplitude modulation ratio (m_a) is difference, the size of the pulse also difference. Both gating signal (gS1 and gS3) and (gS2 and gS4) used the same control signal generated by the microcontroller. The different is only (gS1 and gS3) signal is leading (gS2 and gS4) by half cycle or 180 degree of the switching signal. Figure 3 below clearly illustrated the comparison signal between carrier signal and reference signal and the gating pulses signal (Vg).

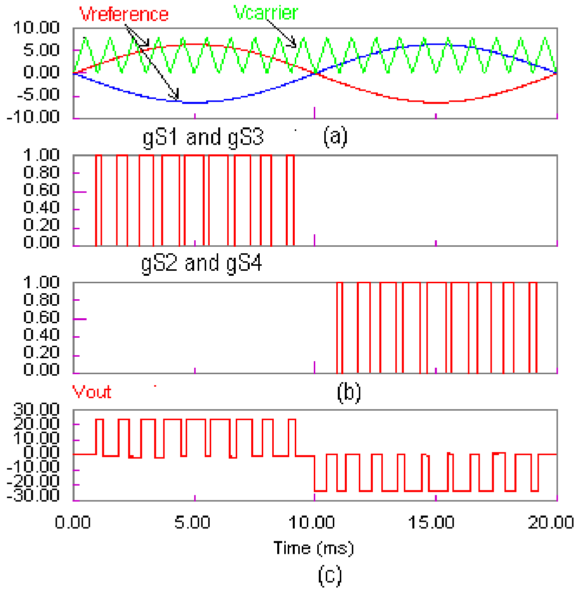

Figure 2: Strategy control of the switching technique

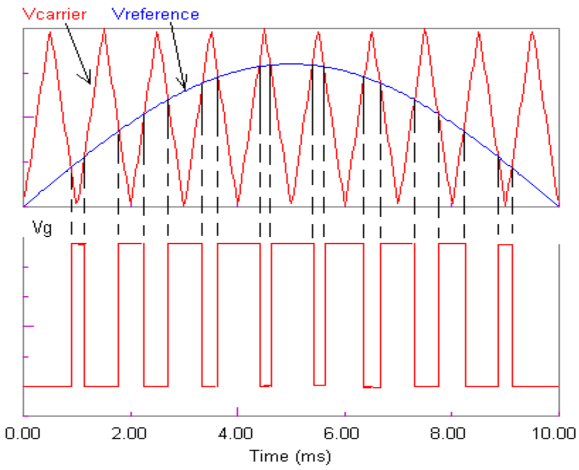

Figure 3: Comparison signal and gating pulses signal

4. Experimental Results and Discussion

The selected results have been chosen to illustrate some of the main features of microcontroller SPWM control, which have been presented in this paper. Figure 4 shows the switching signal for difference amplitude modulation ratio, started from 0.3 until 1.5. Figure 5 shows the output voltage and current for single phase inverter after the filter with amplitude modulation is 1.3.

Figure 4: Switching signal for difference amplitude modulation ratio
(a) m_a =0.3, (b) m_a =0.4, (c) m_a =0.5, (d) m_a =0.6, (e) m_a =0.7, (f) m_a =0.8, (g) m_a =0.9, (h) m_a =1.0, (i) m_a =1.3, (j) m_a =1.5
X-axis: 1div= 1ms, Y-axis: 1div=2V

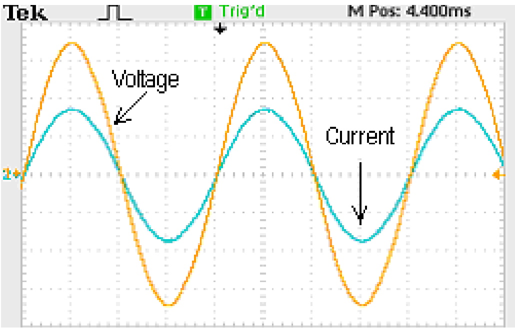

Figure 5: Output of the inverter after filter with resistive load for m_a =1.3 (100V/div), (1A/div)

A comparison of the total harmonic distortion (THD) for difference amplitude modulation ratio shows that the total harmonic distortion increase started from m_a =0.3 until m_a =0.6. Total harmonic distortion for m_a =0.7 to m_a =1.3 is decrease when the amplitude modulation is increase and THD increase back when amplitude modulation ratio, m_a =1.5. This can be seen in Figure 6. A comparison of the dead time period for difference amplitude modulation ratio shows that the dead time period decreases when m_a is increase. This can be seen in Figure 7.

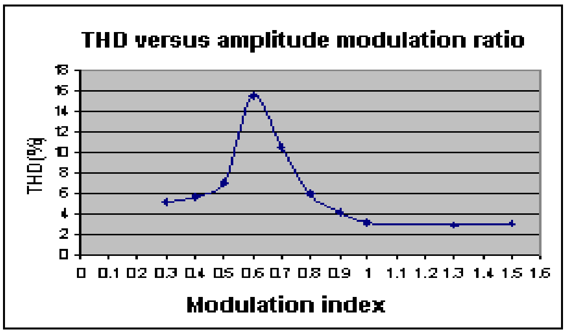

Figure 6: THD versus amplitude modulation ratio

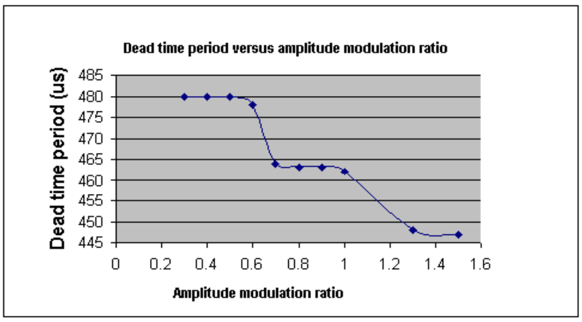

Figure 7: Dead time period versus amplitude modulation ratio

5. Conclusion

The main task in this work is to find the best switching pulses generated by microcontroller with difference amplitude modulation ratio. Amplitude modulation ratio, m_a =1.3 produced good total harmonic distortion for both voltage and current. THD produced by that signal is less than 3% (after filter). The implementation of the single phase SPWM switching signal using microcontroller is placed on minimization of the hardware requirement, with as many functions as possible being performed in the software. Using microcontroller unit, the amplitude modulation ratio and duty cycle can be easily change through programming without further hardware changes.

6. References

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