Small boundary-pulse-width control for dc to ac single-phase inverters

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Abstract: The main purpose of pulse-width –modulation technique for power inverters is to control the output voltage. The most familiar techniques: uniform-pulse-width-modulation and sinusoidal-pulse-width-modulation. This paper proposes new techniques for improving the inverter performance. The methods are based on pulse-width technique. A variation of pulse-widths for the middle and boundary pulses is implemented, to reduce the harmonic effect and obtaining an improved inverter operation. Result in reduced harmonics of the inverter output voltage and an optimum operation is obtained through using small boundary-pulse-width technique.

Keywords: Pulse-width–modulation control, DC to AC inverters, Harmonic control, Energy conversion.

1 Introduction

The purpose of an inverter is to change a dc input voltage to an ac output voltage of a desired magnitude and frequency [1]. The changeable inverter gain provides an efficient control drive [2,3]. A variable inverter output voltage can be obtained by varying the gain of the inverter, which is achieved using pulse-width –modulation (PWM) [4, 5, 6]. This technique causes a discontinuity in the inverter output voltage and harmonics are produced [7, 8]. Therefore, many techniques are developed and tried to reduce the harmonic contents of inverter output voltage and getting acceptable inverter operation based on low distorted sinusoidal output voltage. The most common types of switching techniques are the single-pulse-width-modulation, uniform pulse-width-modulation and sinusoidal-pulse-width-modulation; all are tried to improve the performance of the inverter operation.

This paper describes new types of switching control that implement a form of pulse-width-modulation. These two techniques are the small boundary-pulse-width and large boundary-pulse-width. A control strategy based on variation of pulse-widths for the middle and boundary pulses is developed, to reduce the harmonic effect and obtaining an improved inverter operation. Based on minimum harmonic contents in the inverter output voltage, results are shown that the small boundary pulse-width technique is more adequate and more effective.

2 Harmonic Profile

The main function of an inverter is to convert a dc input voltage to an ac output voltage. The output voltage of a practical inverter is non-sinusoidal waveform and contains harmonics, whereas a low distorted output voltage is needed. A variable inverter gain can be obtained using the switching technique, which is accomplished by pulse-width –modulation (PWM). Different switching techniques are developed to modify the gating angles of the inverter driver, and thereby to improve the inverter operation based on minimum harmonic contents in the inverter output voltage. The single-pulse-width-modulation technique produces only a one-pulse-width per half cycle [1]. The generation of different values of gating angles for the inverter driver, results in variable pulse-widths, leading to a variable inverter operation. Due to switching technique implemented by this method, the output voltage is discontinuous. Its harmonic profile showed that the prevalent harmonics are the third and fifth components [1]. In the uniform-pulse-width-modulation technique (UPWM), multiple pulses of equal widths per half cycle are produced [9]. The harmonic profile for this technique showed that the harmonic contents are less than that produced by the single-pulse-width-modulation technique [1]. The width of each pulse can be changed using the sinusoidal-pulse-width-modulation technique [10, 11].

3 Boundary Pulse-Width Technique

In many applications, it is necessary to control the gain of inverters. A variable inverter gain is achieved by applying the switching control which implements the pulse-width-modulation techniques. The harmonic contents in the inverter output voltage are changeable and depend on the control strategy. This paper proposes two new switching techniques that are used to control the inverter gain and to reduce the harmonic effect on the inverter output voltage. The two sections below summarize their control schemes.

3.1 Small Boundary - Pulse - Width Technique

In this technique, instead of generating a one pulse of width (σ) per half cycle of inverter output voltage, several pulses of number (p) are generated. The boundary pulses are given the smaller width and middle pulse is obtained the larger width, as shown in Fig.1. Assuming the number of pulses per half cycle is p.
The uniform-width of multiple-pulse per half cycle is σ_u.

$$\sigma_u = \frac{\sigma}{p} \qquad (1)$$

The widths of the middle pulse and boundary pulses are determined from equations below. Their sums give the same width of the original pulse (σ) to maintain the same condition for the inverter operation, but will modify the harmonic contents of the inverter output voltage.

Middle-pulse adding (σ_{mA}) is:

$$\sigma_{mA} = \sigma_u \times \left(\frac{p-1}{2}\right) \qquad (2)$$

Middle-pulse width (σ_m) is:

$$\sigma_m = \sigma_u + \sigma_{mA} \qquad (3)$$

and boundary-pulse width (σ_b) is reduce to:

$$\sigma_b = \frac{\sigma_u}{2} \qquad (4)$$

3.2 Large Boundary – Pulse - Width Technique

In this technique, the widths of the boundary pulses are increased, and the width of the middle pulse is decreased by half of the uniform pulse-width (σ_u). Their sums must give the same width of the original single-pulse (σ) of an inverter operation.

Boundary-pulse adding (σ_{bA}) is:

$$\sigma_{bA} = \sigma_u \times \left(\frac{1}{2(p-1)}\right) \qquad (5)$$

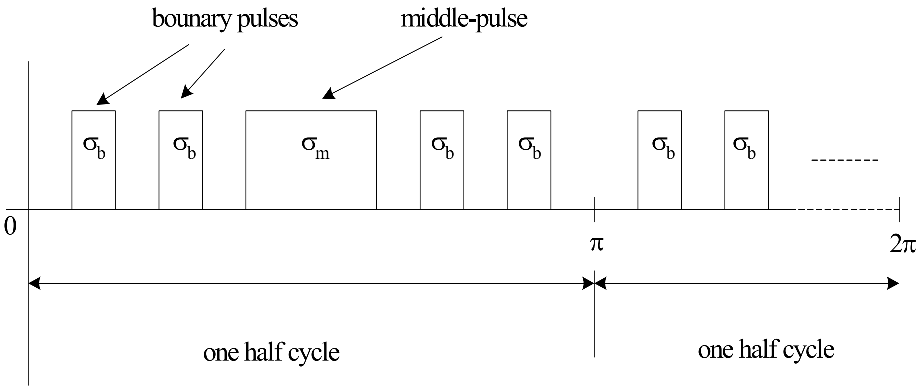

Figure.1 Small-boundary pulse-width technique

Boundary-pulse-width (σ_b)is:

$$\sigma_b = \sigma_u + \sigma_{bA} \qquad (6)$$

and middle-pulse width (σ_m) is:

$$\sigma_m = \frac{\sigma_u}{2} \qquad (7)$$

4 Inverter Performance

Due to the switching control, the inverter output voltage contains harmonics, and the quality of a practical inverter is evaluated in terms of harmonic contents of its output voltage. The harmonic profile for the small boundary-pulse-width technique is shown in Fig.2, with the variation of conduction angle (σ) of the inverter driver. Due to the symmetry of the output pulses for two half cycles, the even harmonics are absent. The prevalent harmonics are the third and fifth component.

5 Results

Instead of generating several pulses of a uniform pulse-width, multiple pulses of variable widths were presented in this paper. Figure.3 shows the third harmonic amplitude of inverter output voltage with the variation of the conduction angle (σ). The results are shown for uniform-pulse-width-modulation technique, small boundary-pulse-width and large boundary-pulse-width techniques. The third harmonic produced by the small boundary-pulse-width technique is at minimum and equals zero for the low range of the conduction angle. Figures.4 and 5 show the ninth and eleventh harmonic amplitudes of inverter output voltage for different control techniques. It can be seen that harmonic contents are reduced for the small boundary-pulse-width technique as the harmonic order is increased, and it is zero for the eleventh harmonic. The number of pulses (p) per half cycle has a high effect on the harmonic amplitude. Figure.6 shows the third harmonic amplitude as a function of the number of pulses per half cycle (p), using small boundary-pulse-width technique. It is clear that as the number of pulses (p) is increased as the harmonic amplitude is decreased, results in an optimum inverter operation of less harmonic contents.

6 Conclusions

The paper has represented a new pulse-width modulation technique for power inverter to control the output voltage and more important to improve the inverter performance. The technique was developed for determination of the variable-pulse durations of different pulses to achieve an optimum inverter operation based on minimum generation of harmonics. The small boundary-pulse-width technique has shown that the harmonic contents in the inverter output voltage were minimum compared with the other methods. Another advantage for the small boundary-pulse-width technique is that the number of pulses per half cycle can be modified to provide an optimum inverter operation.

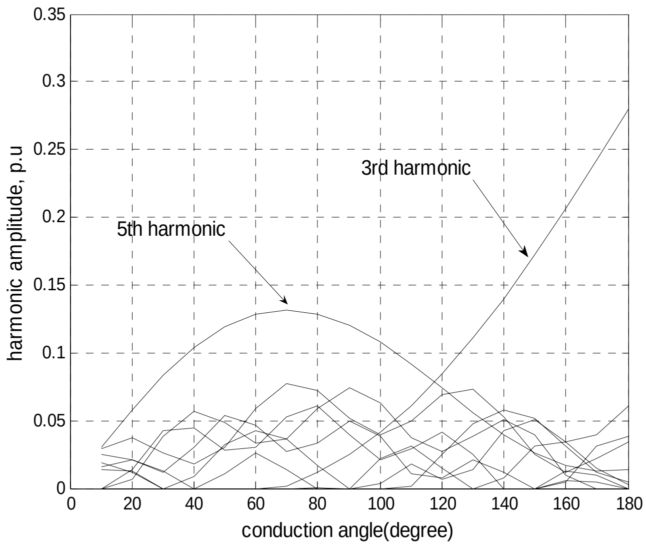

Figure.2 Harmonic profile for small-boundary pulse-width technique

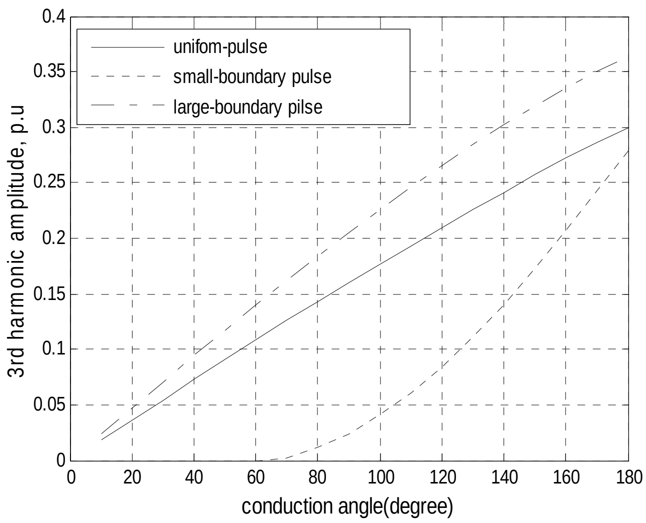

Figure.3 3rd harmonic amplitude for different techniques

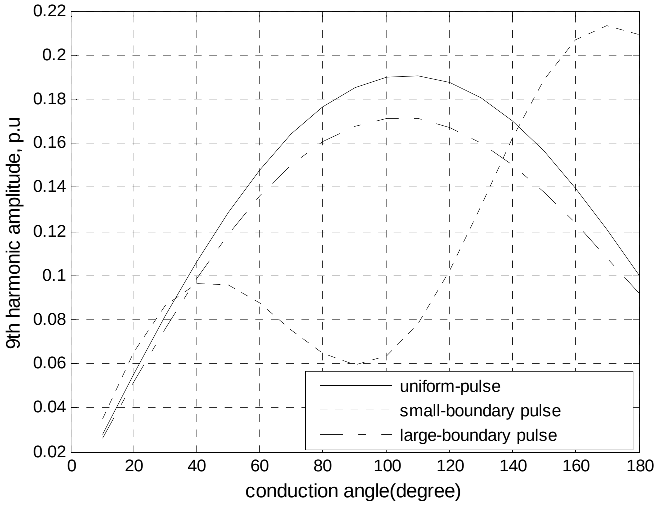

Figure.4 9th harmonic amplitude for different techniques

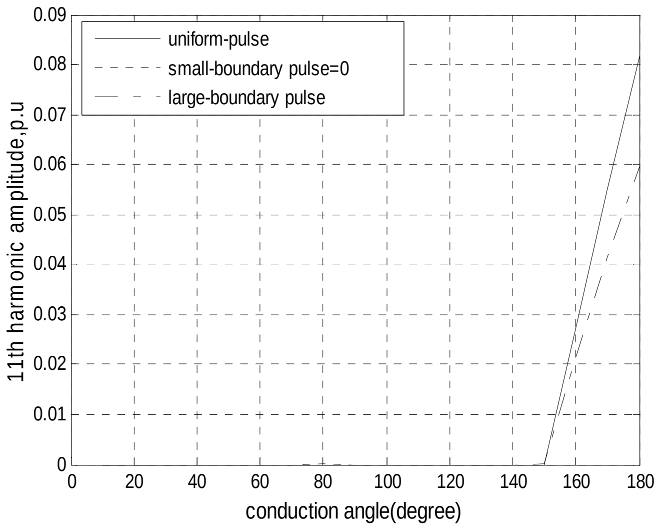

Figure.5 11th harmonic amplitude for different techniques

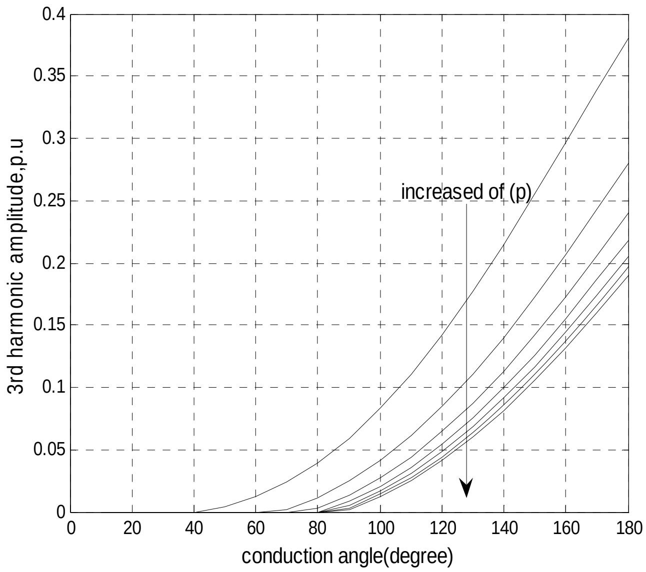

Figure.6 Small-boundary pulse-width technique for p=3, 5, 7…, 15

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