
A Review of All Possible Control Strategies for AC Voltage Controller

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Abstract

AC voltage controllers have wide applications starting from domestic to industry. This paper focuses on the all possible control strategies for controlling or varying the input ac voltage. The paper also provides simulation of all control techniques using MATLAB SIMULINK software.

Keywords: AC – AC Voltage Controller, Control Strategies, MATLAB SIMULINK, Total Harmonic Distortion (THD).

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1. Introduction

AC voltage controller is a power electronic circuit in which fixed ac is converted to variable ac without changing the frequency. The converter circuit consists of SCR as switches and provides variable ac to the load. Applications that benefit from ac voltage controller are [4]: Speed control of induction motor, Industrial heating and lighting, on load tap changing transformers, soft start of induction motors, ac magnet controls, etc. The most commonly used power electronic circuit for controlling the ac voltage is using two SCR's connected in anti-parallel between source and load. The control strategy depends upon the gate pulse given to the SCR's.

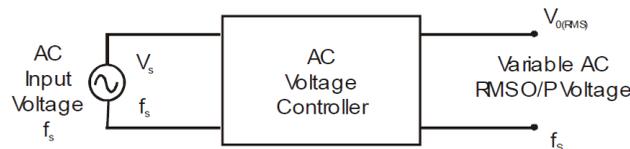


Fig 1: AC Voltage Controller

The control strategies available to control the output voltage are [1], [2] and [3]:

- | | |
|-------------------------------------|---|
| a) On – Off cycle control | d) Pulse Width Modulation (PWM) control |
| b) Phase angle control | e) Section control |
| c) Integral cycle switching control | |

- f) Sector control
- g) Section control with PWM
- h) Sector control with PWM
- i) Phase control with PWM
- j) Integral cycle PWM control

2. AC Voltage Controller

The circuit diagram for single phase ac voltage controller is shown in the Fig. 2. It consists of two SCR's connected in anti-parallel. A TRIAC based voltage controller can be also used for applications up to 400Hz, if TRIACs are available to meet the voltage and current ratings of a particular application [4]. Some control techniques such as phase angle control, on-off cycle control, integral cycle switching control works on line commutation technique and hence SCR's can be used as power electronic switch. But the control techniques such as PWM control, Section control, Sector control and other integrated techniques require IGBT switches to turn on and off when required [6]. Further, it is concluded that IGBTs should not be used as power switch without harmonic filters, since use of IGBT only results in large amount of distortion in the input voltage to the induction motors which may results in instability of the drive system [5].

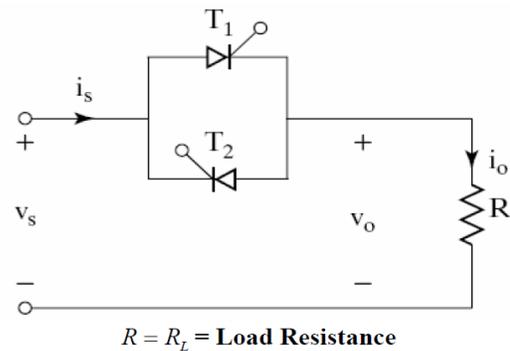


Fig 2: Circuit Diagram

The above control techniques can be implemented in the same circuit diagram choosing proper pulse generation method to turn on and off the switches to obtain respective output voltage patterns. The various control strategies listed above are simulated with resistive load using MATLAB SIMULINK software and suitable waveforms are shown below.

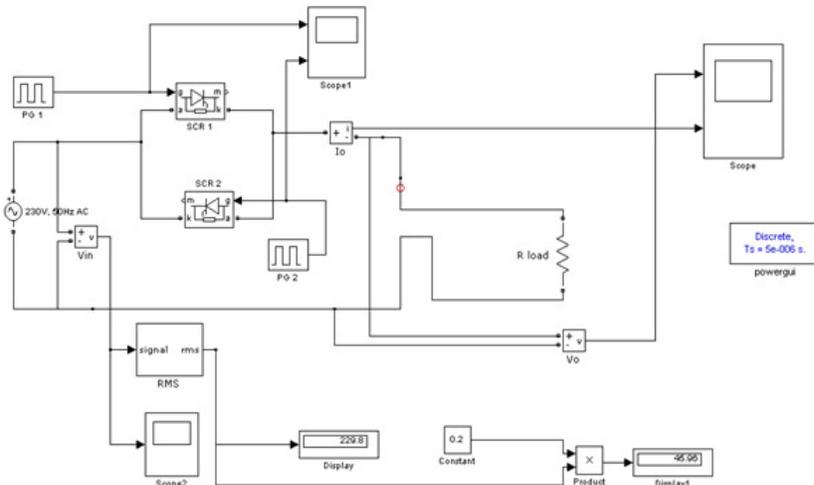


Fig 3: MATLAB simulation diagram

3. On – Off Cycle Control

The output voltage is controlled by triggering the SCRs such that the entire cycle appears across the load for 'n' number of cycles and load voltage is zero for 'm' number of cycles. Hence in this

method of control, the shape of the input waveform is not changed but the input voltage does not appear across the load continuously.

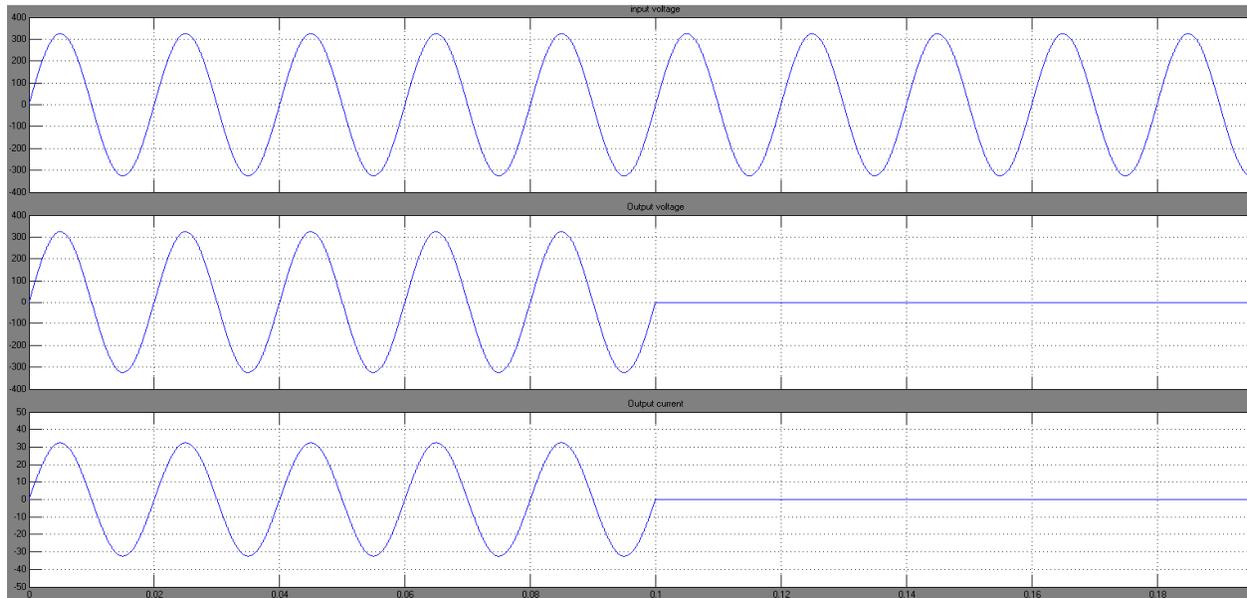


Fig 4: Input and output waveforms

Therefore in this method the %THD should be less and the drawback being load has to sustain the voltage variations i.e., A full supply voltage during the ON period and zero voltage during the OFF period and output voltage control is not continuous. Here SCR's are turned on at zero crossing and duty cycle (ratio of on-time period to total time period) can be varied to vary the output voltage.

4. Phase Angle Control

In this method, the output voltage is controlled by triggering the SCRs T1 and T2. By varying the firing angle the rms value of output voltage is varied [4]. The advantage of this method is continuous output voltage control is possible by varying the firing angle and no commutation circuit is required. Since the sine wave pattern is getting changed, harmonics will be introduced in the system and hence %THD will get increased.

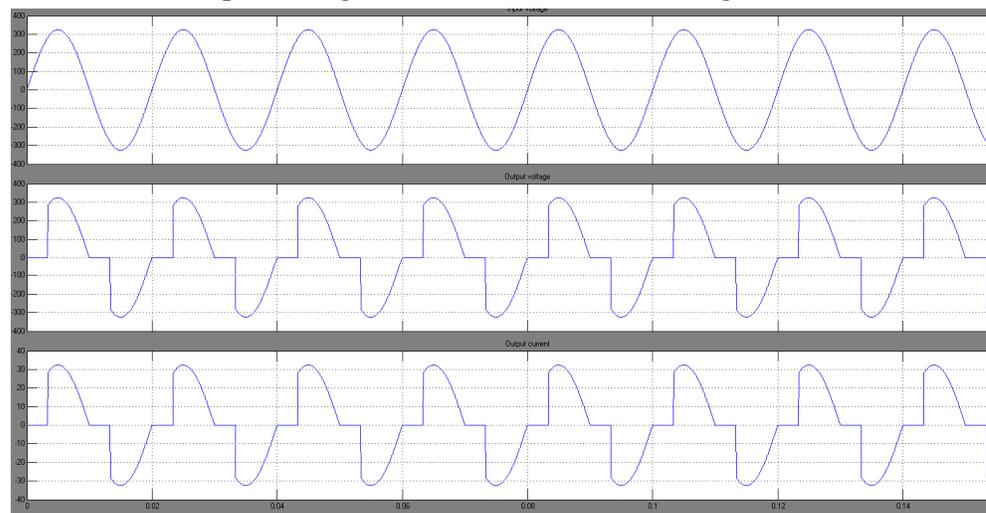


Fig 5: Input and output waveforms

5. Integral Cycle Switching Control (ICSC)

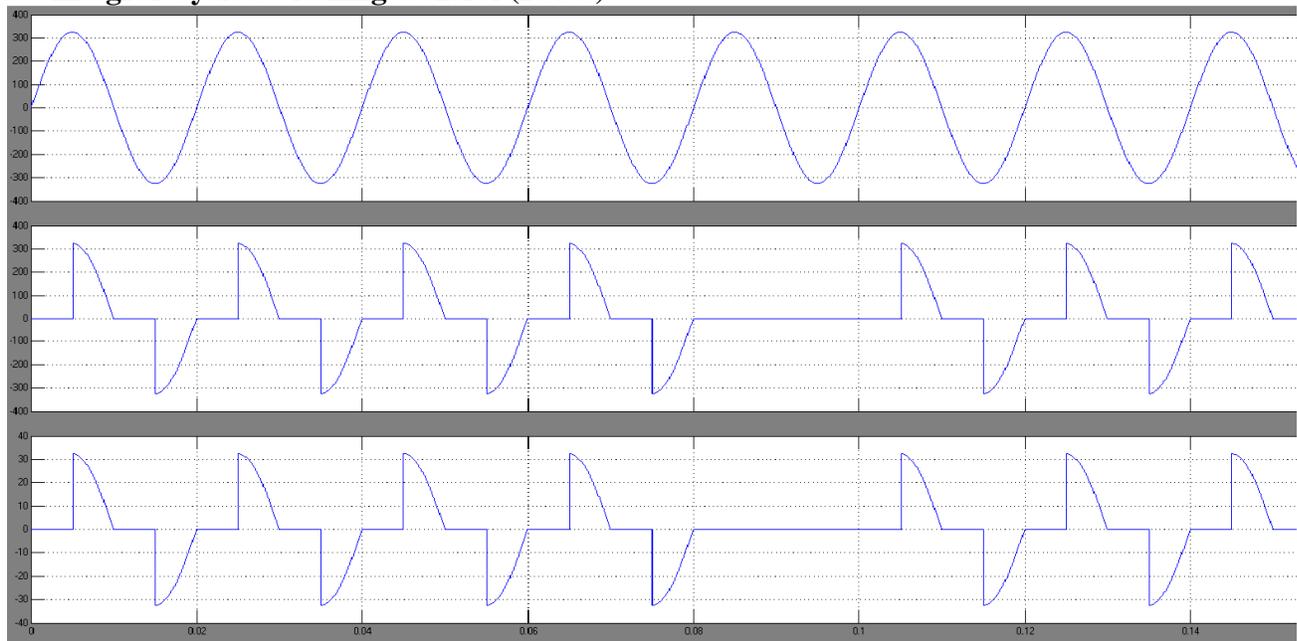


Fig 6: Input and output waveforms

This method is the combination of on-off cycle and phase angle control. The disadvantages of above two techniques are eliminated in this method [1]. The methods by which output voltage is controlled are: a) Keeping firing angle constant and varying duty cycle b) Keeping duty cycle constant and varying firing angle. Thus by this method both continuous control over output voltage is achieved and also %THD is reduced compared to phase angle control.

6. Pulse Width Modulation (PWM) Control

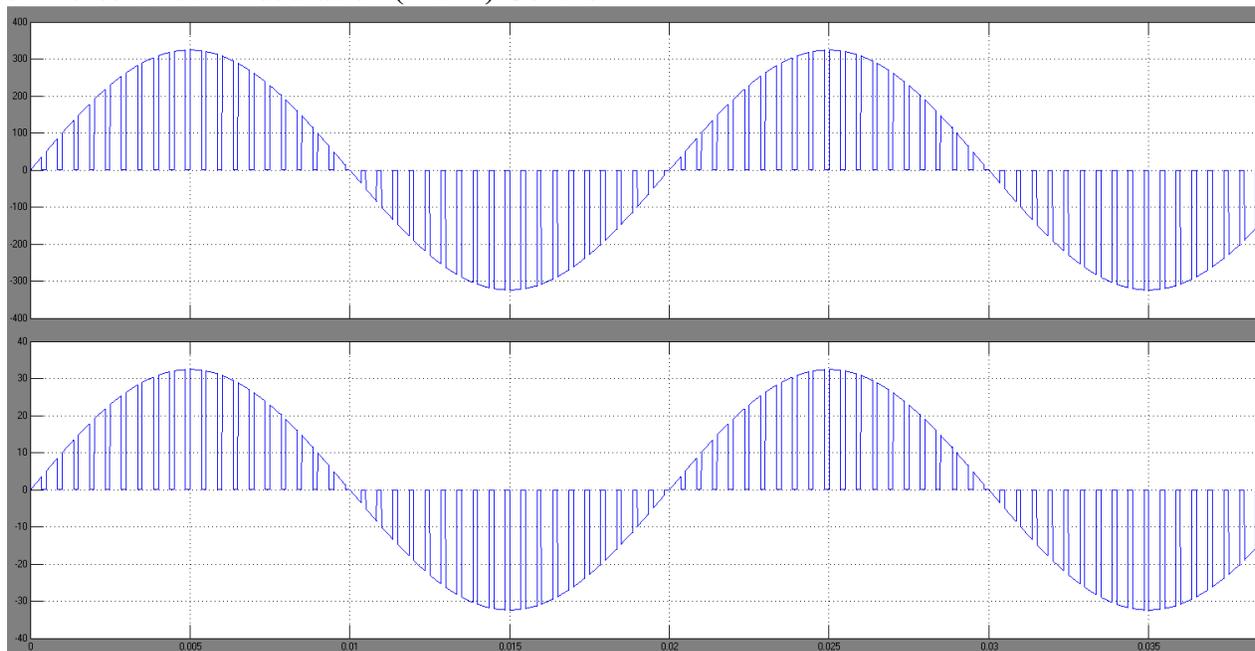


Fig 7: Output voltage and current waveforms

Repeated turning on and off the power electronic switch helps to produce the above pattern. With inductive load, PWM control proves effective with improved power factor. IGBT can be used as power electronic switch since gate has full control over the device. This pattern of output also provides nearly sinusoidal output, better transient response, elimination of lower order harmonics, and small input output filter parameters [2]. The main disadvantage being high switching loss and complex commutation circuit requirement.

7. Section Control

In this method of control SCR's are turned on at zero phase angle delay. The output voltage is varied by varying the conduction angle. This method is similar to phase angle control since they use similar or same part of the waveform. They have same harmonic spectrum and %THD values symmetrically with phase angle control. But the % THD is higher than sector control [3].

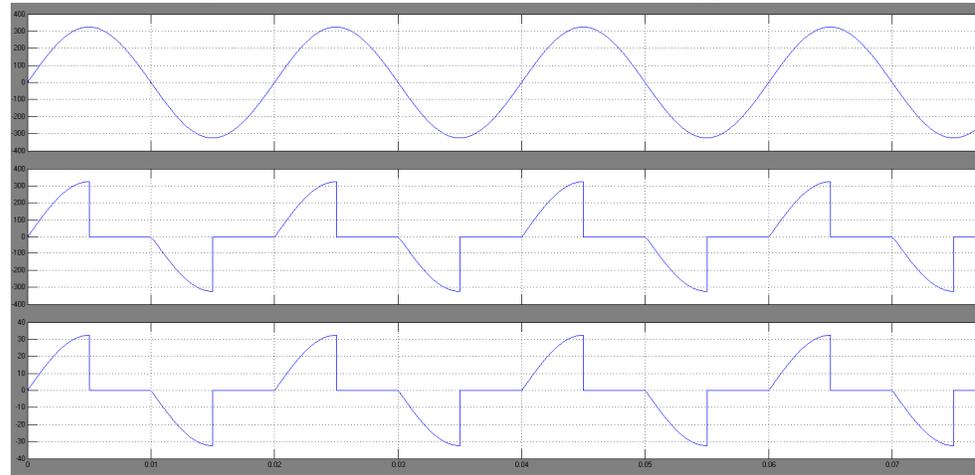


Fig 8: Input and output waveforms

8. Sector Control

The sector control uses middle sections of the positive and negative half-wave cycles. Positive part of this waveform is symmetric at the point of $\omega t = \pi / 2$ radians and negative part of that is symmetric at the point of $\omega t = 3\pi / 2$ radians.

The main advantage of this method is %THD is low compared to phase angle and section controlled ac voltage controller.

The disadvantage is commutation circuit requirement [3].

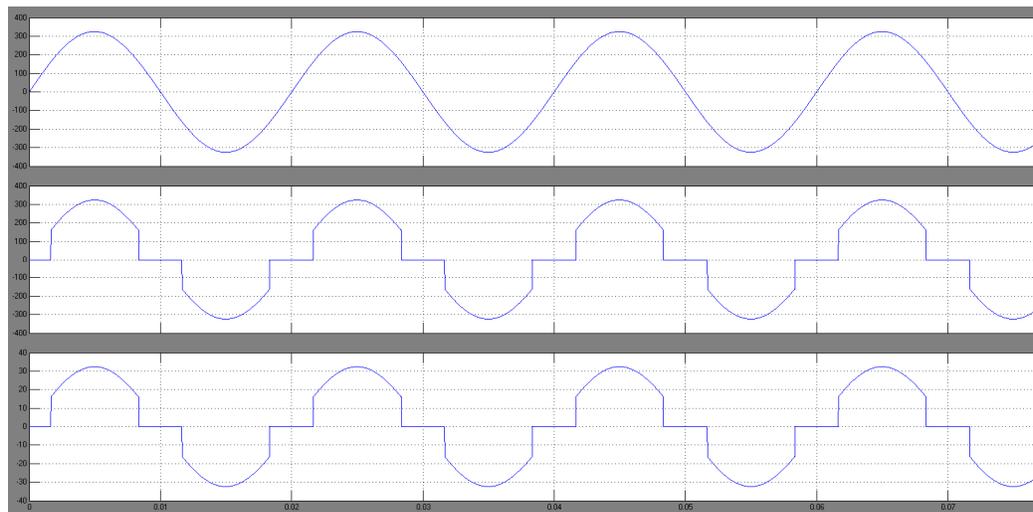


Fig 9: Input and output waveforms

9. Phase Angle Control with PWM

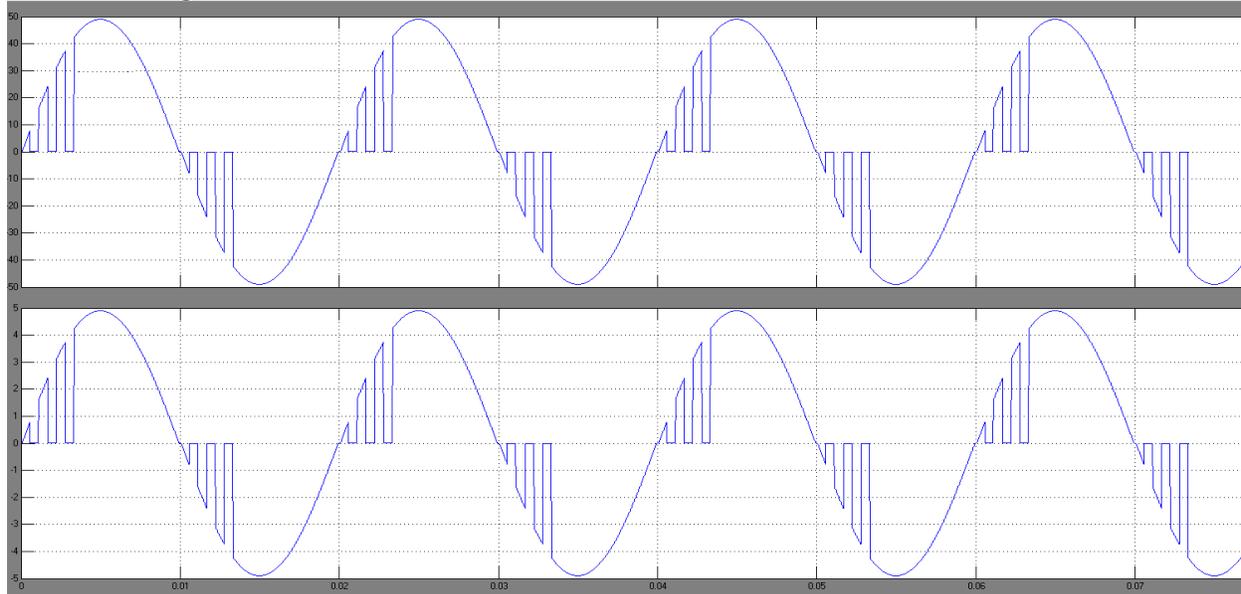


Fig 10: Output voltage and current waveforms

It is the combination of phase angle control and PWM control. This is done to achieve approximately sinusoidal output waveform and hence to reduce %THD [3].

10. Section Control with PWM

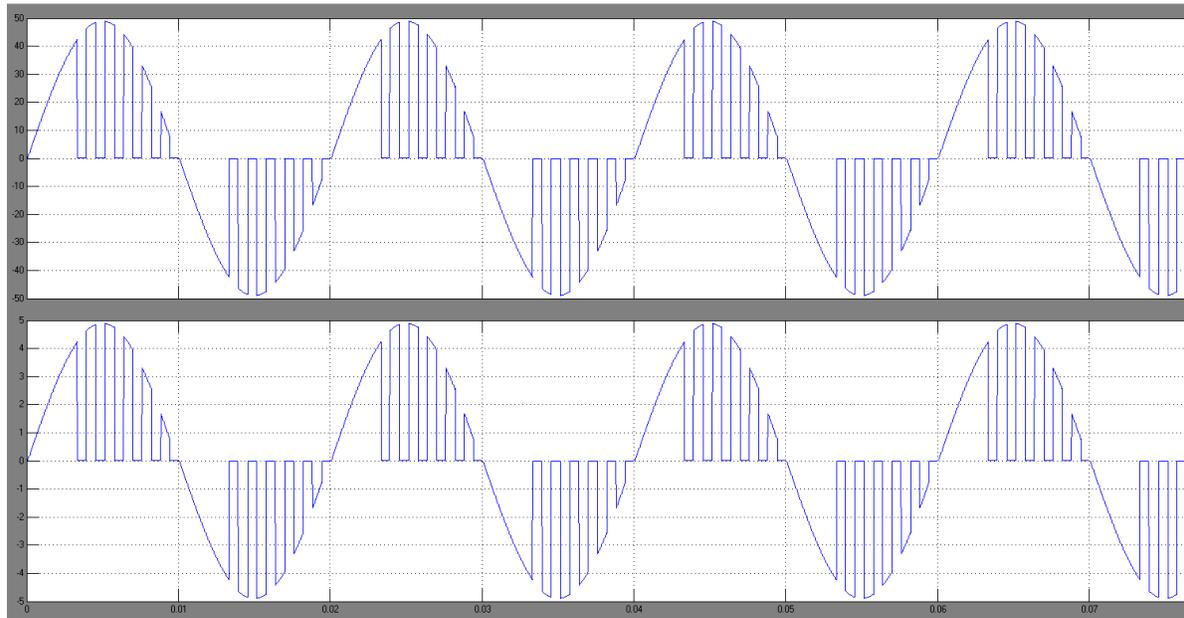


Fig 11: Output voltage and current waveforms

It is symmetrical with Phase angle control with PWM. At higher conduction angles %THD is higher but the magnitude is less than the conventional PWM. At lower conduction angles it generates a few lower order harmonics [2].

11. Sector Control with PWM

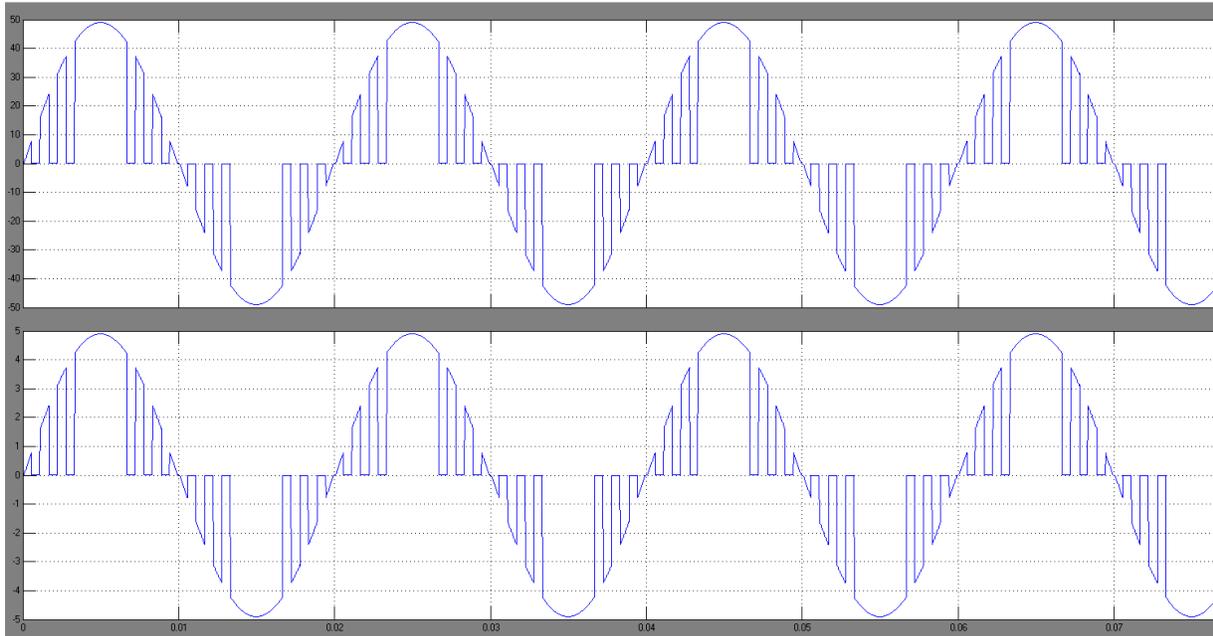


Fig 12: Output voltage and current waveforms

When compared to convention PWM it produces same higher order harmonics but the magnitude is lesser. For higher conduction angles %THD is high but as conduction angle decreases % is low [2].

12. On Off PWM Control

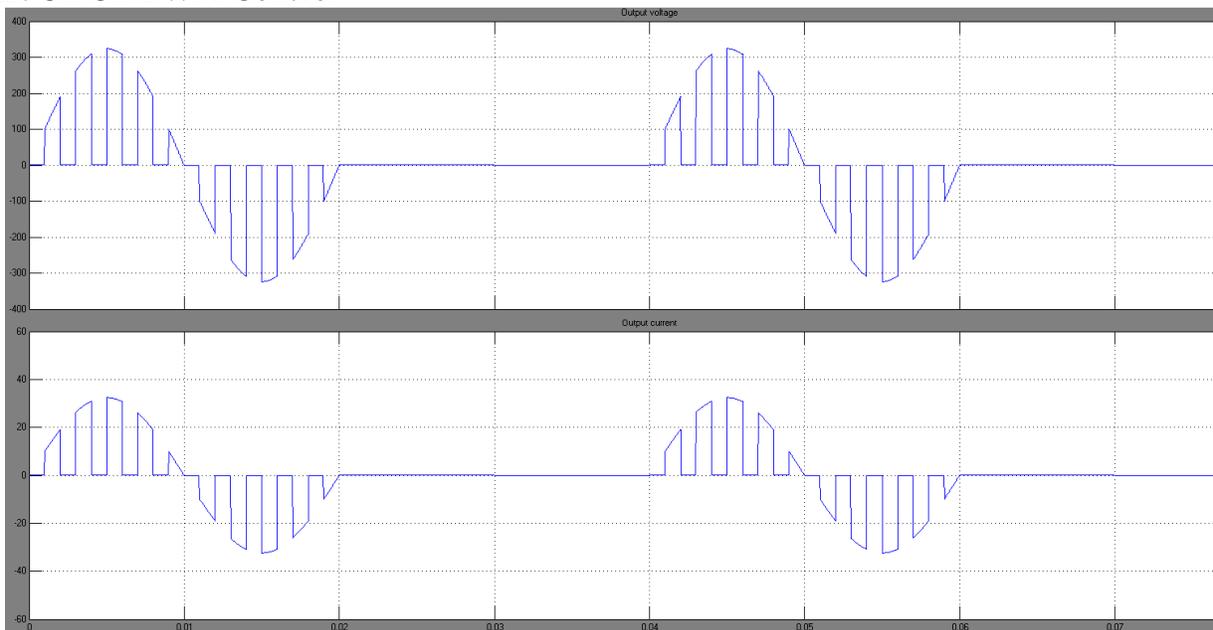


Fig 13: Output voltage and current waveforms

Having studied all the above possible control strategies in literature, in this paper a new pattern of output voltage is proposed which combines the on – off cycle and PWM control techniques. This technique of switching when compared to Integral cycle switching control should produce

less %THD since the output voltage pattern is almost sinusoidal and output voltage can be controlled by varying the pulse width. Commutation requirement has to be considered before implementation.

13. Conclusion

The all possible control strategies of AC voltage controller used to control the output voltage is discussed in this paper. MATLAB simulation is provided to ensure the users that all switching techniques are possible and before going for implementation the parameters such as effectiveness in output voltage control, %THD, commutation circuit requirement, cost of the entire system, power electronic switch requirement, etc., need to be compared and the best method can be used for suitable application.

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