Design and simulation an open loop AC chopper converter with an RL load with the approach of reducing the output and input total harmonic distortion

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ABSTRACT

In this article an open loop AC chopper is designed and simulated. The load side of the converter consists of a resistance and an inductance. The aim of this paper is to achieve both an output with low total harmonic distortion and an input with low total harmonic distortion as a result a high power factor both in the output side of the converter and in the input side of the converter will be seen; therefore the power losses during the power transmission process will be decreased but the power quality parameters in the converter will be improved. There are two main control methods for switching the power electronic switches in this converter; open loop control method and closed loop control method. In this article open loop control method is considered.

Keywords: **AC chopper, AC-to-AC converter, Total harmonic distortion**

1. *INTRODUCTION*

AC chopper is one of the AC-to-AC converter types which converts the AC input to an AC output with another voltage's amplitude and frequency and phase characteristics. Such a process is done by the two parallel bi-directional switches in the converter which each of these two switches is on when the other switch is off. Each of these two switches consists of two IGBTs; each of these IGBTs have a diode which is in series with its corresponding IGBT that protects the IGBT from the reverse voltage. In this paper a digital gate of NOT is used following a pulse width modulation generator in order to force the power electronic switches work in complementarity with each other therefore a different sinusoidal voltage amplitude will be appeared in the output side of the converter. The control method in this paper is based on the open loop method which means the output doesn't depend on the input.

1.1 Background

This paper presents a novel robust control technique for PWM ac choppers with the ability to generate high quality sinusoidal waveforms with adjustable amplitudes over a wide range control.[1] A method of voltage harmonic elimination in a pulse-width modulated AC/AC voltage converter using genetic algorithms (GA) is proposed. The output voltage of the AC chopper with k pulses per half cycle is written in terms of switching angles using Fourier series, and the best switching angles are identified with the dual objectives of harmonic elimination and output voltage regulation.[2] This study presents a new current-limiting soft-starter for a three-phase induction motor drive system using pulse width modulation (PWM) AC chopper. A novel configuration of three-phase PWM AC chopper using only four insulated gate bipolar transistors (IGBTs) is also proposed.[3] In this work, a novel driver circuit is designed for permanent split capacitor motors (PSC). With this driver circuit, semi-conductive technology is used in place of cumulative winding for this type of motors that are particularly used in kitchen exhaust fans. Developed circuit is controlled via PWM method.[4] In this paper, a control system is presented based on sliding mode control (SMC) for a three-phase three-wire dynamic voltage restorer to compensate for voltage sag and swell. This dynamic voltage restorer (DVR) system includes an AC/AC converter in each phase without energy storage and DC link.[5]

2. ***Main discussion***

In this article an AC chopper on the base of the open loop control method with the switching frequency of 10 KHZ is designed and simulated. The peak of the input voltage source is 310 V on the frequency of 50 HZ. The proposed converter's circuit is shown in the figure 1.

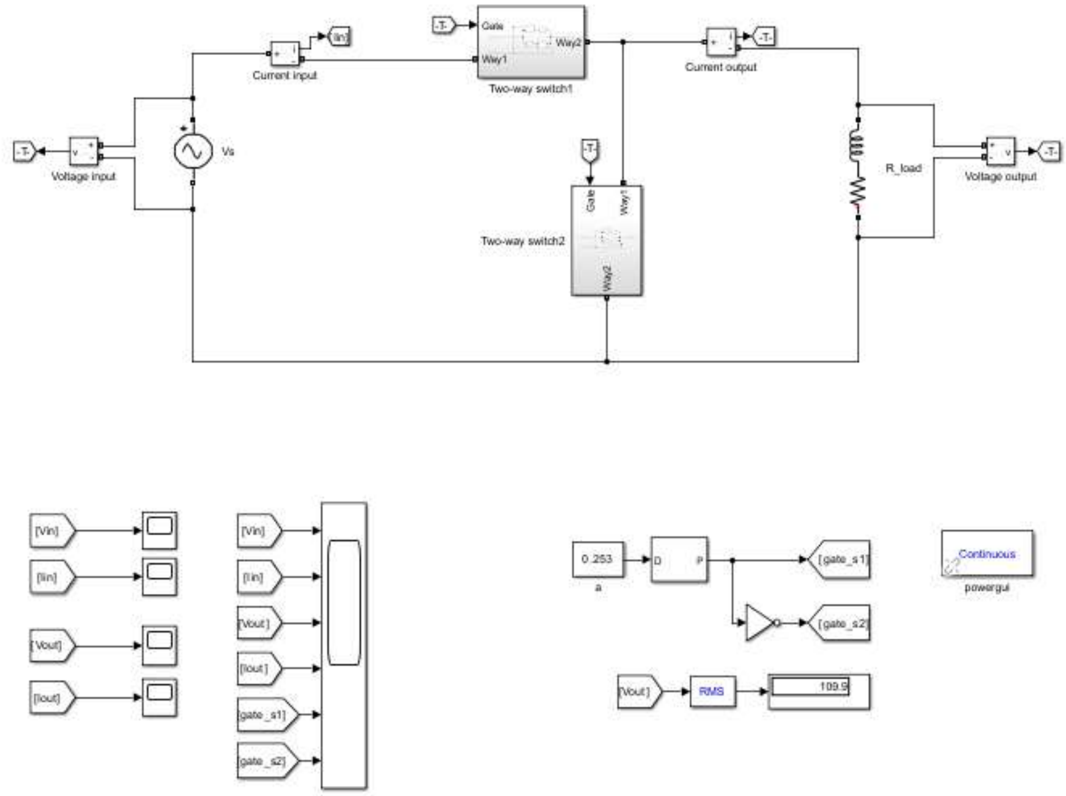

Fig. 1. The proposed converter's circuit

As it is able to be seen in the figure 1 two bi-directional power electronic switches are parallel connected to each other following after an AC voltage source; then an RL load is connected to this system which the resistance of the load side is 100 ohms and the inductance of the load side of the converter is 500 mH. Each of these switches initial circuit is shown in the figure 2.

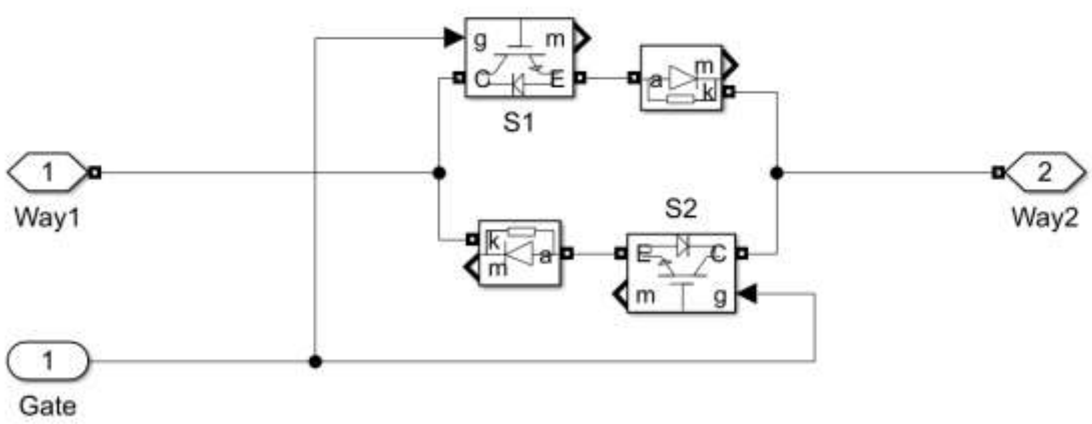

Fig. 2. Each of bi-directional power electronic switches initial circuit

As it can be seen in the figure 2 each of the power electronic switches consists of two anti-parallel IGBTs series with diodes; these diodes protect the IGBTs against the reverse voltage. As it can be seen in the figure 1 the current of each of the power electronic switches gates is complementary to the other. This means when each of the switches is on the other one is off; therefore, the output voltage's waveform will be different. In *this converter in the periods in which one of the switches is on the other one is off; symmetrically in the Complementary periods each of the switches performs inversely as a result the output voltage waveform in the second period will be different complementarily.*

3. Simulation results

In this paper an AC chopper with the open loop control method of switching the power electronics switches with the switching frequency of 10 KHZ is designed and simulated. Such a switching frequency is generated by the pulse width modulation generator as it can be seen in the figure 1 and then injected into the IGBTs gates in both of the power electronics switches in the converter's topology; one of the switches got the major signal but the other switch got the complementary waveform of the major signal.

In the figure number 3 the input voltage waveform can be seen and also in the figures number 4 to 6 the input current waveform, the output voltage waveform and the output current waveform respectively is able to be seen.

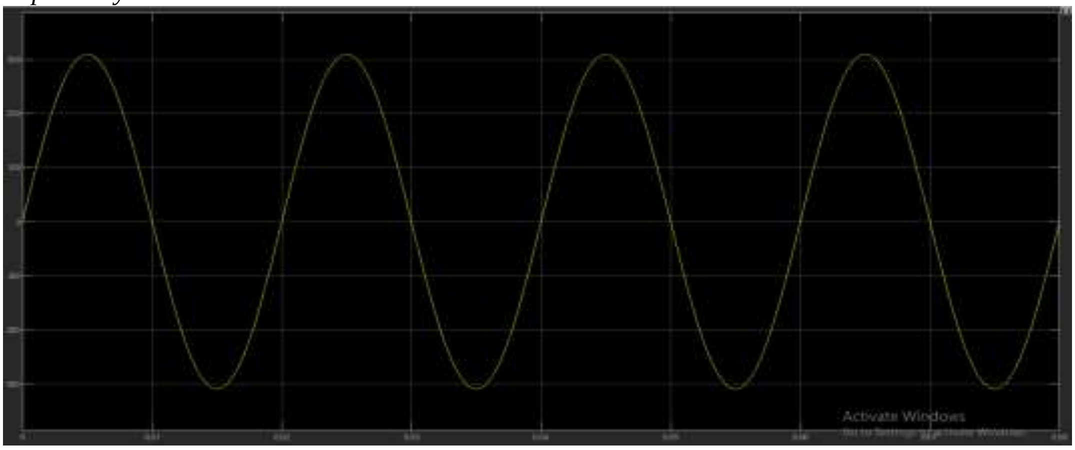

Fig. 3. The input voltage waveform

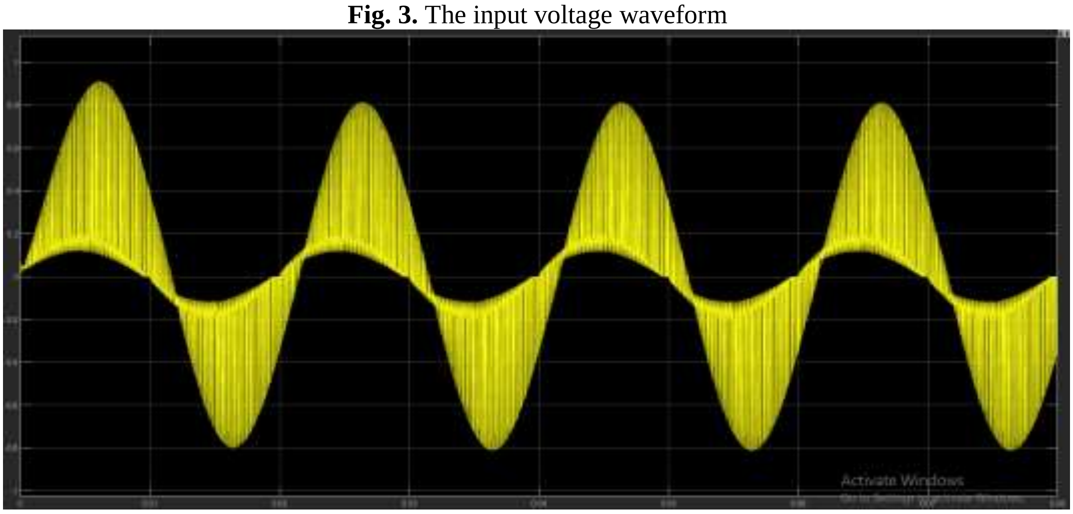

Fig. 4. The input current waveform

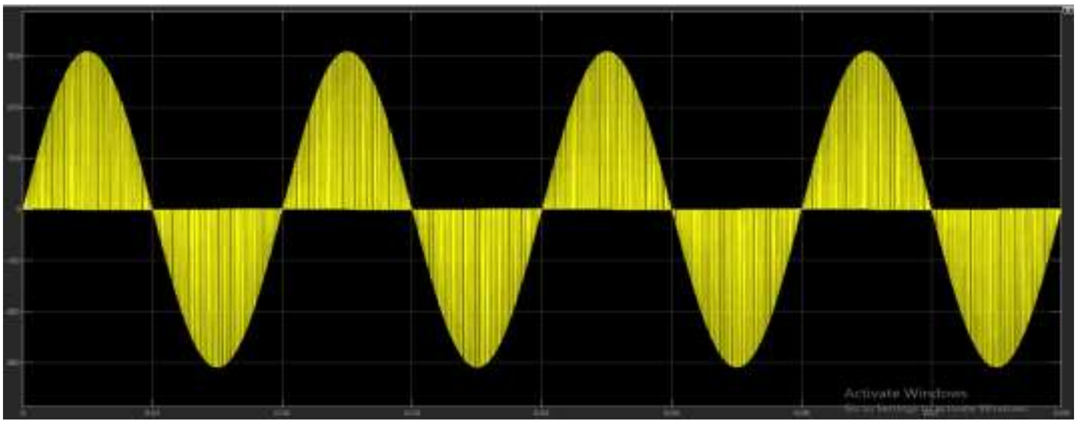

Fig. 5. The output voltage waveform

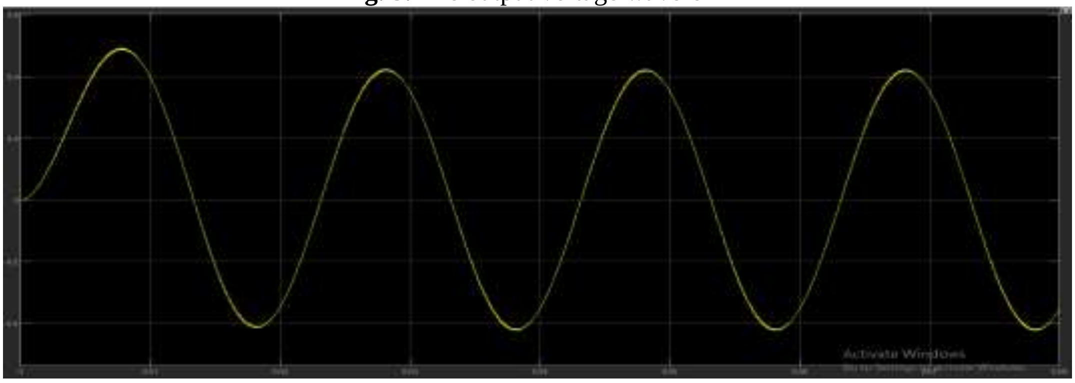

Fig. 6. The output current waveform

In the next two figures the PWM generator waveform which is injected into the gate of the two way switch number 1 and the PWM generator waveform after the digital gate of NOT which is injected into the gate of the two way switch number 2 in the figure 1 is able to be seen.

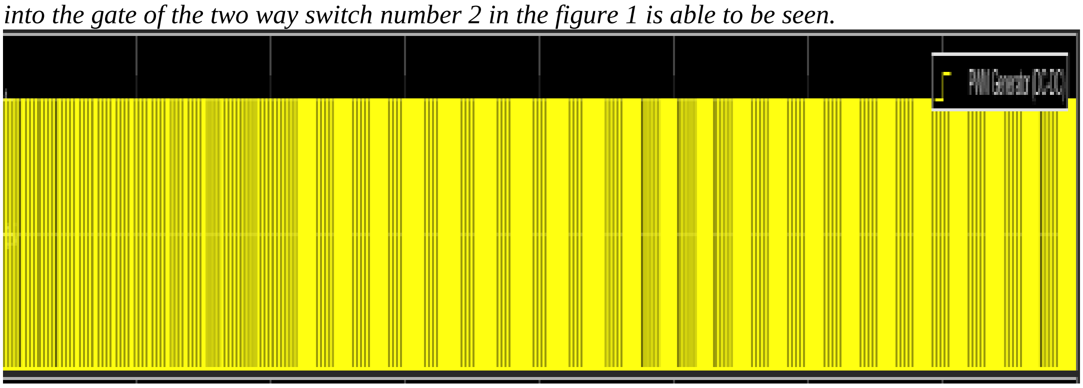

Fig. 7. The PWM generator waveform

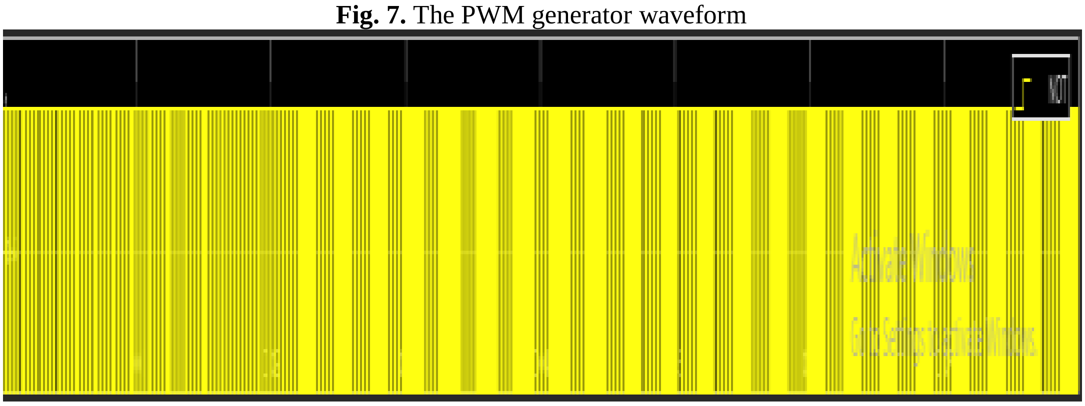

Fig. 8. The PWM generator waveform after the digital gate of NOT

As it can be seen from the figures above in the section 3 of the paper a different voltage waveform's amplitude is appear in the output side of the converter.

In the next figures the total harmonic distortion of the both input voltage and output voltage and also the input current and the output current can be seen.

Sampling time	=	9.26591e-07 sec.
Samples per cycle	=	21585
DC component	=	7.733e-06
Fundamental	=	310 peak (219.2 rms)
THD	=	0.00%

0 Hz	DC	0.00%	90.0°
16.6667 Hz	---	0.00%	-0.3°
33.3333 Hz	---	0.00%	-0.0°
50 Hz	Fnd	100.00%	0.0°
66.6667 Hz	---	0.00%	179.9°
83.3333 Hz	---	0.00%	179.9°
100 Hz	h2	0.00%	179.4°
116.667 Hz	---	0.00%	179.8°
133.333 Hz	---	0.00%	179.7°
150 Hz	h3	0.00%	178.1°

Fig. 9. The total harmonic distortion percentage of the input voltage waveform

Sampling time	=	9.26591e-07 sec.
Samples per cycle	=	21585
DC component	=	0.007531
Fundamental	=	0.308 peak (0.2178 rms)
THD	=	4.85%

0 Hz	DC	2.45%	90.0°
16.6667 Hz	---	4.34%	63.3°
33.3333 Hz	---	3.41%	45.0°
50 Hz	Fnd	100.00%	-13.3°
66.6667 Hz	---	2.14%	27.8°
83.3333 Hz	---	1.78%	23.3°
100 Hz	h2	1.51%	20.5°
116.667 Hz	---	1.30%	18.3°
133.333 Hz	---	1.14%	17.7°
150 Hz	h3	0.96%	10.6°

Fig. 10. The total harmonic distortion percentage of the input current waveform

Sampling time	=	9.26591e-07 sec.
Samples per cycle	=	21585
DC component	=	0.03204
Fundamental	=	78.3 peak (55.37 rms)
THD	=	1.46%

0 Hz	DC	0.04%	270.0°
16.6667 Hz	---	0.07%	233.0°
33.3333 Hz	---	0.07%	222.6°
50 Hz	Fnd	100.00%	0.6°
66.6667 Hz	---	0.06%	168.4°
83.3333 Hz	---	0.06%	139.4°
100 Hz	h2	0.05%	75.2°
116.667 Hz	---	0.04%	36.1°
133.333 Hz	---	0.04%	40.6°
150 Hz	h3	0.26%	215.7°

Fig. 11. The total harmonic distortion percentage of the output voltage waveform

Sampling time	=	9.26591e-07 sec.
Samples per cycle	=	21585
DC component	=	0.02909
Fundamental	=	0.4221 peak (0.2984 rms)
THD	=	13.16%

0 Hz	DC	6.89%	90.0°
16.6667 Hz	---	12.24%	62.7°
33.3333 Hz	---	9.58%	44.1°
50 Hz	Fnd	100.00%	-52.6°
66.6667 Hz	---	6.02%	26.0°
83.3333 Hz	---	5.00%	21.2°
100 Hz	h2	4.26%	17.7°
116.667 Hz	---	3.69%	15.1°
133.333 Hz	---	3.24%	13.2°
150 Hz	h3	2.84%	13.6°

Fig. 12. The total harmonic distortion percentage of the output current waveform

As it can be seen in the figures number 9 to 12 the total harmonic distortion of the output voltage and the output current and the input voltage and also the input current is too decreased by using the open loop control method of the IGBTs; as a result, the power factor of both of the input side of the converter and the output side of the converter is increased.

4. Conclusion and future works

In this article an AC chopper with the open loop control method of the IGBTs of the converter is designed and simulated. The total harmonic distortion parameter of both input side of the converter and also the output side of the converter is decreased by using such a control method. Therefore, the power factor of the converter will be increased in both input side of the converter and also the output side of the converter. At last, the power losses during the power transmission process in this converter will be near to zero joules as a result the power quality parameters in this converter will be improved.

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