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

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ABSTRACT

In this article a closed 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 closed 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 closed loop method which means the output depend on the input.

1.1 Background

This study proposes an automatic voltage regulator (AVR) based on series voltage compensation with an ac chopper. The proposed AVR is made up of a pulse-width-modulated (PWM) ac chopper and a transformer for series voltage compensation. In the ac chopper, the commutation problem is solved by switching patterns.[1] Multiple pulse width modulated (MPWM) AC choppers are gaining popularity over phase controlled circuits mainly due to the minimization of harmonics and the improvement in the input power factor.[2] LC filters are connected to both the input and output side of the AC chopper circuit in order to remove the switching ripple and harmonics. Characteristics of THD and input power factor are examined by simulation and experiments. When the load is resistive, characteristics are minimally influenced by the filters.[3] Genetic algorithm (GA)-based harmonic elimination technique is proposed for designing AC chopper. GA is used to calculate optimal firing angles to eliminate lower order harmonics in output voltage. Total harmonic distortion of output voltage is taken for the fitness function used in the GA. Thus, the ratings of the load are not mandatory to be known for calculating the switching angles using proposed technique.[4] A three-phase ideal phase shifter using pulse-width modulation (PWM) AC choppers is proposed. The ideal phase shifter is made up of three single-phase PWM AC choppers and transformers for series quadrature *voltage injection. The proposed phase shifter uses PWM AC choppers to solve the commutation problem and produces phase shift without amplitude variation.[5]*

2. *Main discussion*

In this article an AC chopper on the base of the closed loop control method with the switching frequency of 10 KHZ is designed and simulated. The input voltage source consists of two AC voltage sources. The peak of one of the input voltage sources is 310 V on the frequency of 50 HZ and the other one is 210 V on the frequency of 50 HZ. The proposed converter's circuit is shown in the figure 1.

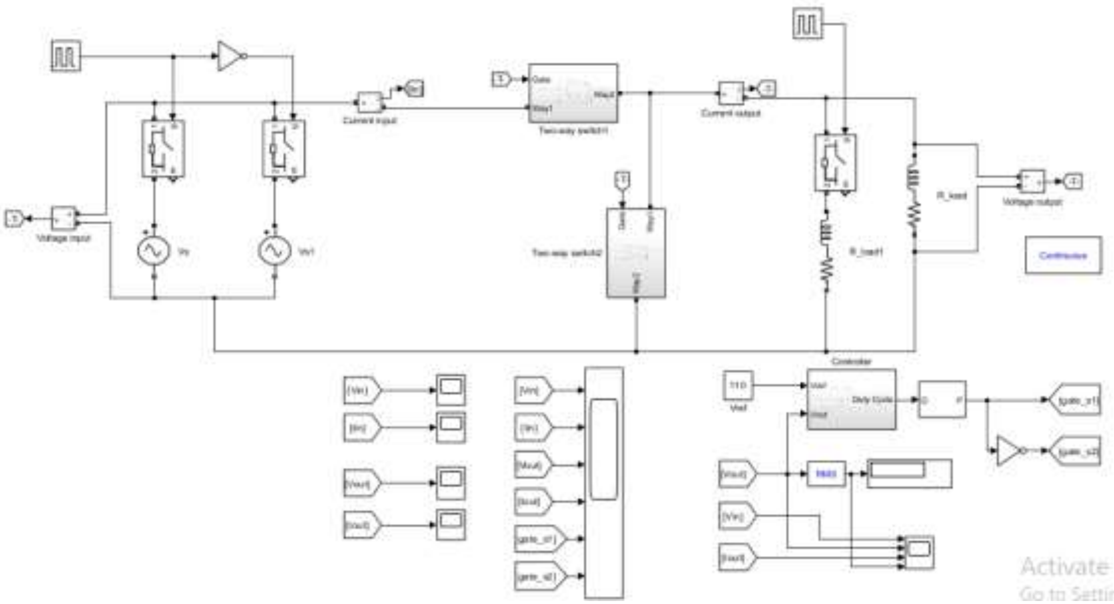

Fig. 1. The proposed converter's circuit

As it is able to be seen in the figure 1 the load side of the converter consists of resistance and inductance. The switching frequency of the power electronic switches which in the figure 1 are named two-way switch is 10 KHZ. The parallel bi-directional switch's initial circuit is given in the figure 2.

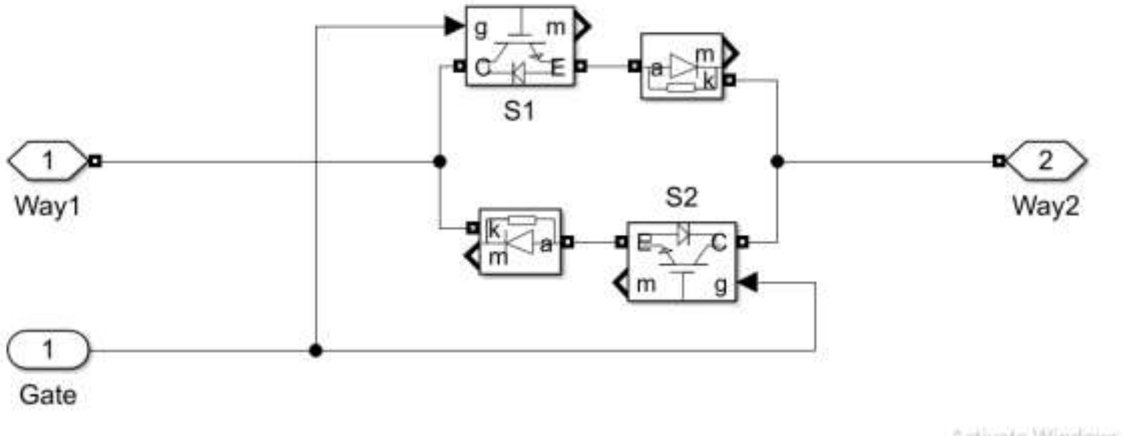

Fig. 2. The parallel bi-directional switch's initial circuit

As it can be seen in the figure 2 two anti-parallel IGBTs is used in the circuit which each of them is series with a diode which is designed to protect its corresponding IGBT against the reverse voltage. These IGBTs work on the switching frequency of 10 KHZ. Then these two parallel power electronic switches work complementary to each other; this means a digital gate of NOT force the second power electronic switch work when the first one doesn’t work; this makes an output with another amplitude, phase and frequency. This is exactly the AC chopper’s performance.

The load 1 consist of a resistance with a magnitude of 10 ohms and an inductance with a magnitude of 50 mH complementarily the major load consists of a resistance with a magnitude of 100 ohms and an inductance with a magnitude of 500 mH.

The output voltage will be decreased from the reference voltage in the figure 1 in the controller block then the result signal’s steady state fault will be corrected by a PID-controller after that the output signal will injected into the pulse width modulation generator and then be used in the IGBT’s gates on the converter’s switching frequency.

The reference voltage is 110 V.

3. Simulation results

In this paper an AC chopper with the closed 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 controller block 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.

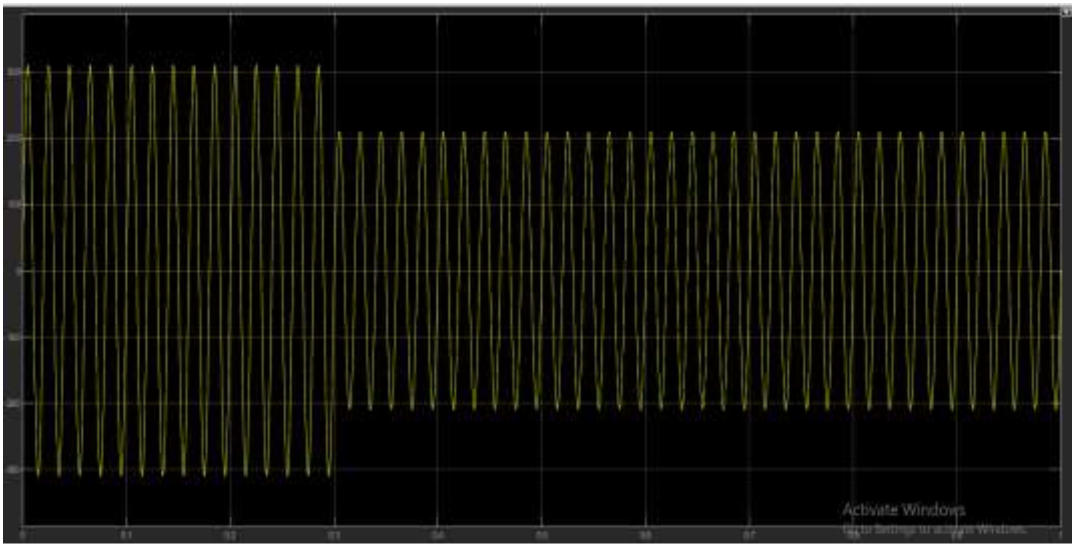

Fig. 3. The input voltage waveform

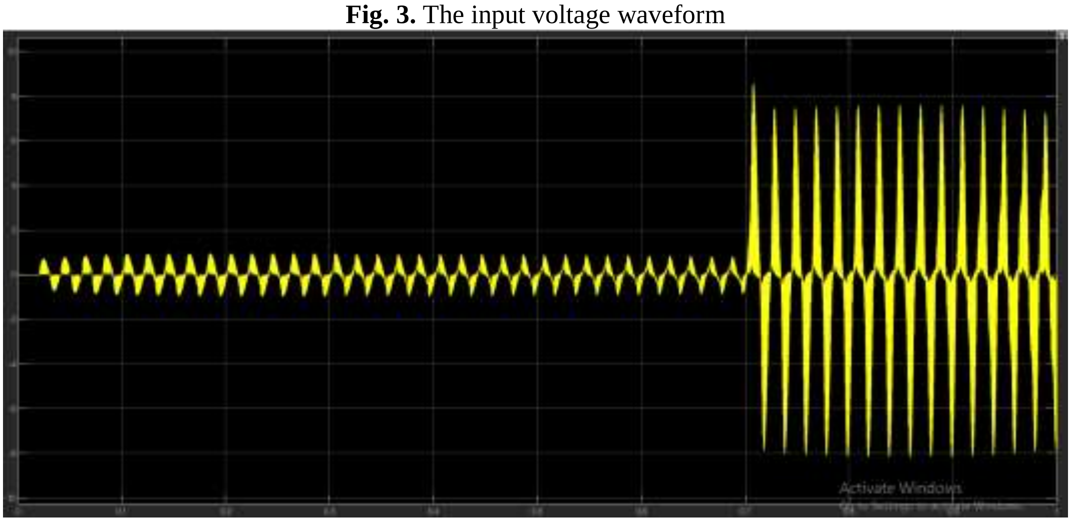

Fig. 4. The input current waveform

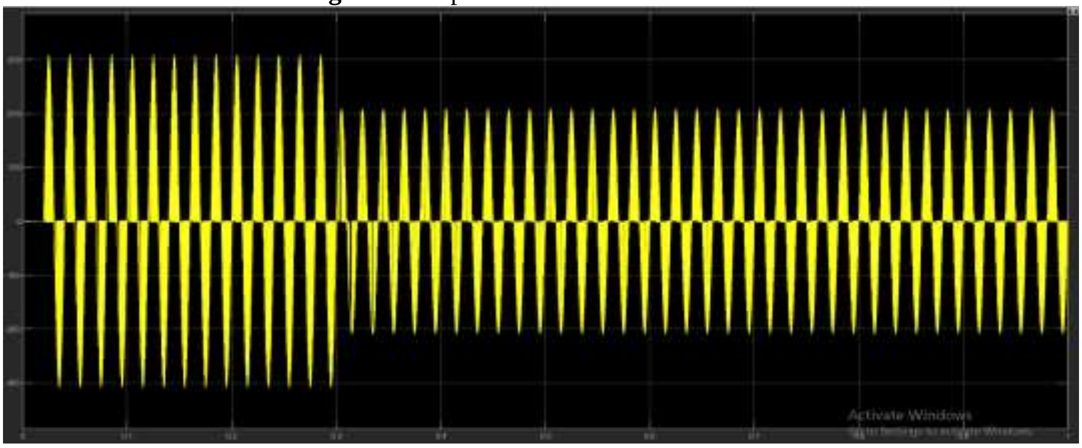

Fig. 5. The output voltage waveform

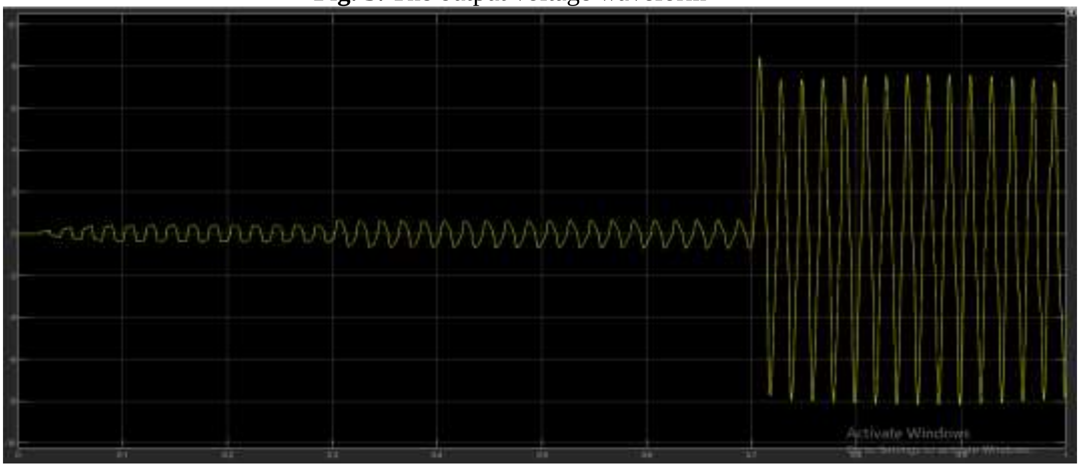

Fig. 6. The output current waveform

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.

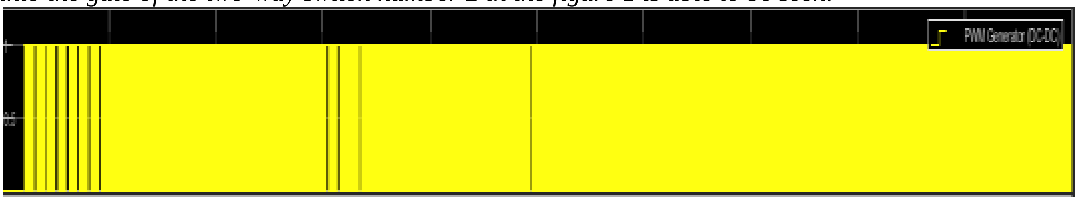

Fig. 7. *The PWM generator waveform*

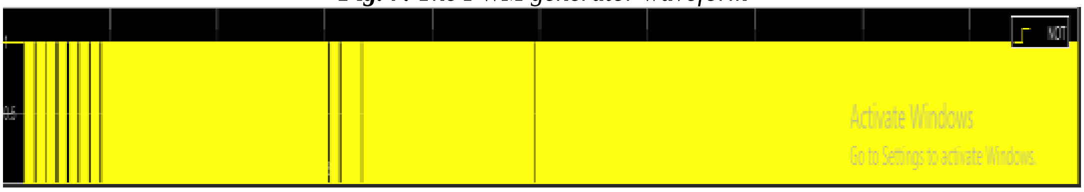

Fig. 8. *The PWM generator waveform after the digital gate of NOT*

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 = 8.54598e-07 sec.
Samples per cycle = 23403
DC component = 0.0001548
Fundamental = 310 peak (219.2 rms)
THD = 0.00%

0 Hz	DC	0.00%	270.0°
16.6667 Hz	---	0.00%	189.8°
33.3333 Hz	---	0.00%	178.6°
50 Hz	Fnd	100.00%	-0.0°
66.6667 Hz	---	0.00%	1.9°
83.3333 Hz	---	0.00%	-6.6°
100 Hz	h2	0.00%	-2.9°
116.667 Hz	---	0.00%	0.7°
133.333 Hz	---	0.00%	-12.9°
150 Hz	h3	0.00%	21.8°

Fig. 9. The output voltage waveform total harmonic distortion

Sampling time = 8.54598e-07 sec.
Samples per cycle = 23403
DC component = 0.194
Fundamental = 4.999 peak (3.535 rms)
THD = 26.93%

0 Hz	DC	3.88%	270.0°
50 Hz	Fnd	100.00%	-61.9°
100 Hz	h2	4.01%	-3.7°
150 Hz	h3	22.75%	20.9°

Fig. 10. The input current waveform total harmonic distortion

Sampling time = 8.54598e-07 sec.
Samples per cycle = 23403
DC component = 2.184
Fundamental = 115.5 peak (81.68 rms)
THD = 50.76%

0 Hz	DC	1.89%	270.0°
50 Hz	Fnd	100.00%	-8.3°
100 Hz	h2	2.07%	86.8°
150 Hz	h3	45.81%	30.7°

Fig. 11. The output voltage waveform total harmonic distortion

Sampling time	=	8.54598e-07 sec.
Samples per cycle	=	23403
DC component	=	0.00807
Fundamental	=	0.6307 peak (0.4459 rms)
THD	=	17.58%

0 Hz	DC	1.28%	270.0°
50 Hz	Fnd	100.00%	-48.8°
100 Hz	h2	1.66%	84.8°
150 Hz	h3	16.12%	148.7°

Fig. 12. The output current waveform total harmonic distortion

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 closed 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 closed 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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