

IMPROVING VOLTAGE REGULATION AND ELIMINATION OF HARMONICS IN PWM AC CHOPPER USING ARTIFICIAL INTELLIGENT TECHNIQUE

Mr. S. Saravanakumar
PG Scholar,

Electrical and Electronics Engineering,
K.S. Rangasamy College of Technology,
Namakkal, Tamilnadu, India

Mr. S. Mahendran
Assistant Professor,

Electrical and Electronics Engineering,
K.S. Rangasamy College of Technology,
Namakkal, Tamilnadu, India

Dr. I. Gnanambal
Professor and Head,

Electrical and Electronics Engineering,
Government College of Engineering,
Salem, Tamilnadu, India

Abstract—This paper proposes a harmonic reduction approach and output voltage regulation in pulse width modulation (PWM) based AC Chopper using artificial intelligent technique. The optimal switching angles are provided by artificial intelligent technique to minimize harmonic distortions. In addition, the simulation results are correlated to confirm the performance in terms of power factor by improving the power quality. It can be applied to design optimal switching patterns for other power converter topologies.

Keywords— AC Chopper, Artificial Intelligent Technique, Harmonic Reduction, Pulse Width Modulation.

I. INTRODUCTION

Voltage adaptability has become the major requirement in modern power electronic equipment. In various types of control equipment such as heating, lighting and motor speed controllers, an AC-AC converter has become the major component. Energy efficiency improvements techniques also need soft start control and for power factor correction regular fixed AC sources have to be replaced by the variable voltage converters. Various soft control techniques such as phase angle control have many advantages. In general, phase angle control is used for voltage adaptation. For example, it can be conveniently implemented and exhibits cost effectiveness for large scale applications. However, the delay of the firing angle causes discontinuation of the power flow and significant harmonics to both input and output sides [1][2].

Using the chopping technique, the AC voltage signal is modified as a PWM signal to regulate the output voltage and output current. This approach can provide nearly sinusoidal current and voltage waveforms. In addition, it can improve both power factor and power quality. Since the switching frequency is limited by the switching losses in high power and high voltage applications, harmonic filter techniques are required to eliminate the low harmonic components caused by low frequency choppers [3][4].

In industrial applications, PWM AC Choppers are frequently used as AC voltage transformation circuit to overcome the major disadvantages presented by different AC voltage

controllers and to improve the power quality (PQ) delivered by the power system. On the other hand, the AC Chopper topologies, analogously to the DC choppers, provide direct AC-AC conversion only between two AC sources characterized by the same fundamental frequency [5][6].

The advantage of the AC Chopper over AC voltage controller include

- Improved load power factor due to high frequency switching.
- Control range is wide in terms of firing angles regardless of load power factor.
- The low order harmonics are eliminated compared to the phase angle control.
- The order of the dominant load voltage harmonics can be controlled through changing chopper frequency [8][9].

In this paper, an optimal switching strategy based on FLC for PWM AC Chopper is proposed. FLC is adopted to provide the optimal switching angles of the PWM pattern. The proposed approach aims to minimize the harmonic distortion of converter's output waveforms with satisfying technical constraints of the switching angle sequences.

II. PWM AC CHOPPER

The power circuit design of a PWM AC-AC converter is shown in Figure 1. Switch S_1 controls the power delivered to the load and switch S_2 is the freewheeling path to transfer energy to the load when switch S_1 is turned off. In a predictable PWM AC Chopper, the switching pattern is regularly fixed. This conveys the low order harmonics to the input and output waveforms. A harmonic elimination technique is an adjustment of the switching angles to reduce the waveform distortion. In Fig 2, improved input and output waveforms are shown. Using this technique, the total harmonic distortion is also reduced. In this paper, the best possible switching angles for the PWM AC Chopper are provided by stochastic search approaches. In the PWM chopper approach, the output voltage is controlled by the

switching pattern. Thus, M pulses are essential for a quarter of a sinusoidal cycle. In addition, switch S_1 is turned on at different switching angles $\alpha_1, \alpha_2 \dots \alpha_M$ and turned off at angles $\beta_1, \beta_2 \dots \beta_M$. Using the Fourier series expression, the output voltage can be written as:

$$V_o(\omega t) = \sqrt{2}v_i \left(a_0 + \sum_{n=1}^{\infty} (A_n \sin(n\omega t) + B_n \cos(n\omega t)) \right) \quad (1)$$

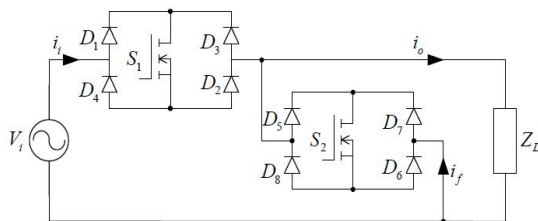


Fig 1: Power Circuit Configuration

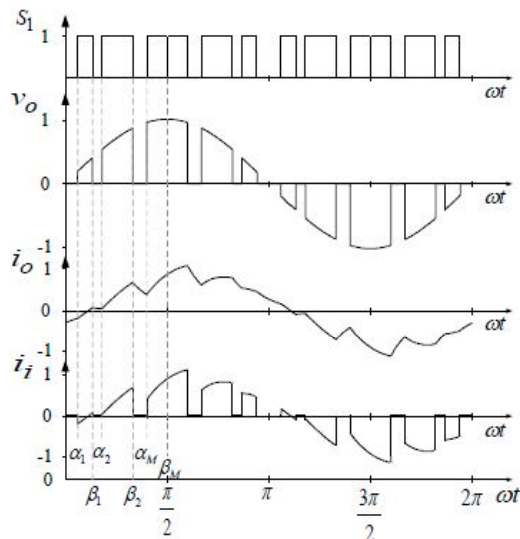


Fig 2: PWM Pattern, Waveforms of Output Voltage, Current and Input Current

$$v_o(\omega t) = \sqrt{2}v_i \left(a_0 + \sum_{n=1}^{\infty} (A_n \sin(n\omega t) + B_n \cos(n\omega t)) \right) \quad (2)$$

Where $n = 1, 2, 3, \dots$

By considering only the odd components of the waveform in (1), the output voltage can be written as:

$$v_o(\omega t) = \sqrt{2}v_i \sum_{n=1}^{\infty} A_n \sin(n\omega t) \quad (3)$$

Where $n = 1, 3, 5, \dots$

The fundamental coefficient A_1 is expressed as:

$$A_1 = \frac{1}{\pi} \sum_{k=1}^M \left[(\beta_k - \alpha_k) - \frac{\sin 2\beta_k - \cos 2\alpha_k}{2} \right] \quad (4)$$

The harmonic coefficient (A_n) is expressed as:

$$A_n = \frac{1}{\pi} \sum_{k=1}^M \left[\frac{\sin((n-1)\beta_k - \sin((n-1)\alpha_k))}{(n-1)} - \frac{\sin((n+1)\beta_k - \sin((n+1)\alpha_k))}{(n-1)} \right] \quad (5)$$

Where switch S_1 is turned on at various switching angles $\alpha_1, \alpha_2 \dots \alpha_M$ and turned off at $\beta_1, \beta_2 \dots \beta_M$, where M is the pulse per quarter cycle.

The THD of the load current and voltage are defined as:

$$THD_i = \frac{\sqrt{\sum_{n=3}^{\infty} I_{0n}^2}}{I_{01}} \quad (6)$$

$$THD_v = \frac{\sqrt{\sum_{n=3}^{\infty} V_{0n}^2}}{V_{01}} \quad (7)$$

Where $n = 3, 5, 7, \dots$

III PROPOSED METHODOLOGY- FUZZY LOGIC CONTROLLER BASED AC CHOPPER

Conventionally PWM based AC chopper is used for voltage regulation. It generates waveform rich in harmonics. Hence Fuzzy based AC chopper is implemented in order to provide switching pulses to the chopper for voltage regulation and thus it reduces the switching losses with a pure sinusoidal waveform of low THD. Fuzzy rules can be implemented based on expert knowledge of the control process, which is treated linguistically in an “if-then” structure. As a consequence, if dispenses with the detailed or precise knowledge of the mathematical model that represents the control plant. The rule base consists of 7x7 matrices [10].

There are two input variables, voltage error and change in voltage error is given to the fuzzy logic controller and the controlled output voltage generates the switching pulses for the AC chopper. Seven linguistic variables for each input variable are used. These are NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZR (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big).

Table 1-Rules table of FLC

Er \ Ch	NB	NM	NS	ZR	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	IZ
NM	NB	NB	NB	NM	NS	ZO	PS
NS	NB	NB	NM	NS	ZO	PB	PM
ZR	NB	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PM	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

The membership functions of each variable are shown in figure 3, 4, 5.

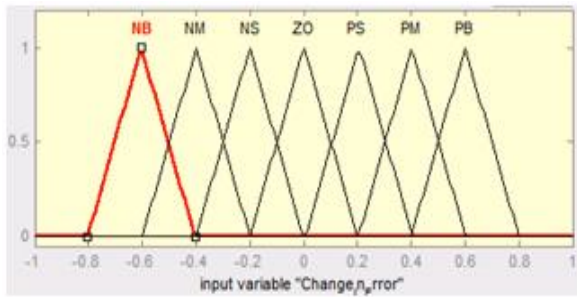


Fig 3: Input Variables -Voltage Error (Er)

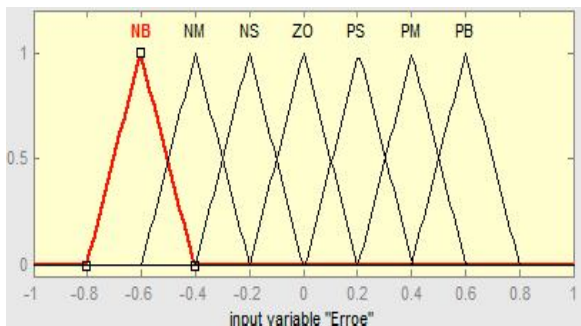


Fig 4: Input Variables -Change in Voltage Error (Ch Er)

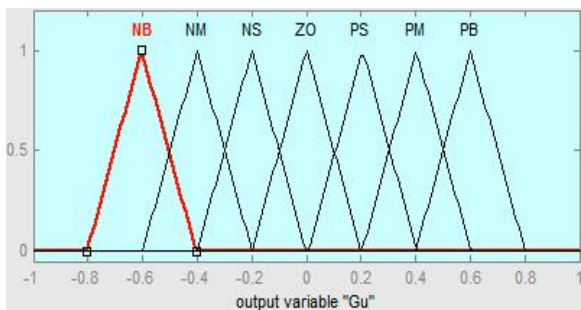


Fig 5: Output Variable

The probability of finding the output variable is 7×7 . Thus 49 rules framed for FLC is shown in table 1. The voltage is regulated with low THD thereby improving the performance of the system.

IV. SIMULATION RESULTS AND ANALYSIS

In this project PWM AC Chopper using FLC technique is proposed. Figure shows the simulation model of proposed method. The 230 V AC input is connected to the AC Chopper with Fuzzy logic controller. The FLC algorithm is implemented to provide optimal switching angle for the AC Chopper. By varying the switching angle, the output voltage is

controlled. So, the performance of the system is enhanced and Total Harmonic Distortion is reduced.

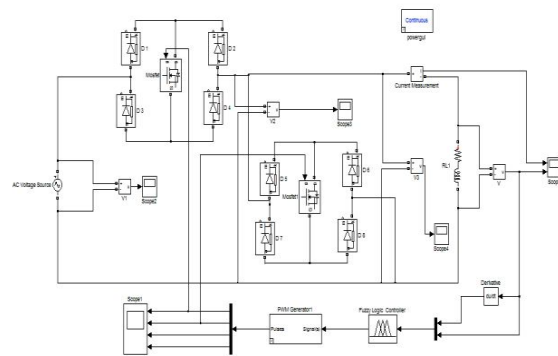


Fig 6 : Simulation Model of AC Chopper

The projected control concept is verified through modeling of the circuit using MATLAB/Simulink.

4.1 Block Parameters of AC Chopper

The table 2 represents the block parameters of the proposed system.

Table 2- Block Parameters

Component	Value
Input source (AC)	240V
Frequency	50Hz
Modulation index M	3
Output resistor, R	240 Ω
Output Inductor, L	300 mH

4.2. Simulation Results

The Switching pattern for PWM AC Chopper shown in Figure7. Its switching pattern is generated from the fuzzy logic controller.

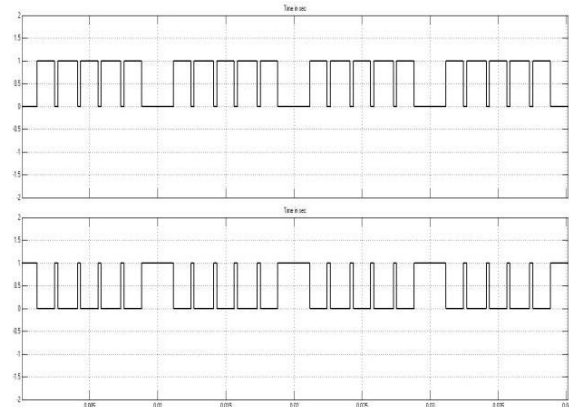


Fig 7: Switching pattern for AC Chopper

The simulation Result of output voltage and current waveforms shown in Fig 8.

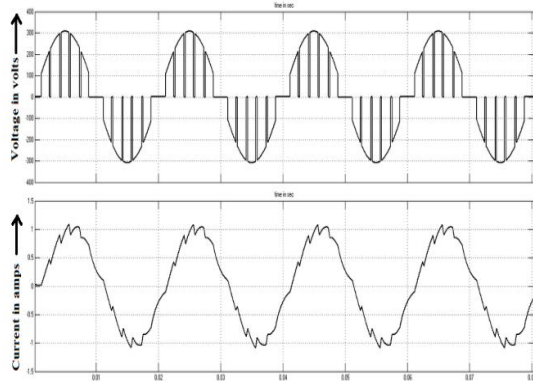


Fig 8: Simulation Result of Proposed System

A FLC is adopted to generate the PWM for controlling the gate signals of the switching devices. The converter can vary the output voltage in the range of 20-220. Finally we can get the output voltage as 120 V_{rms} .

4.3 FFT Analysis of Ac Chopper

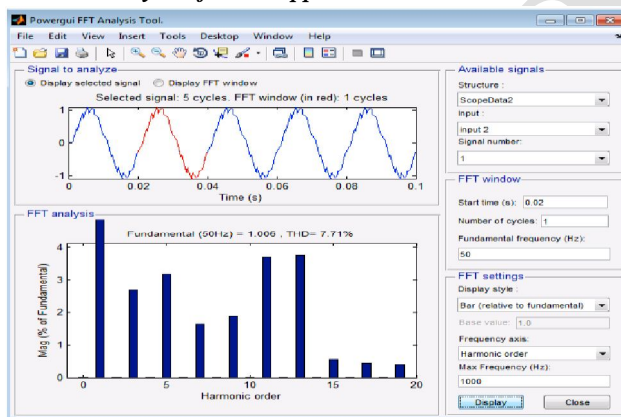


Fig 9: FFT Analysis of Pulse Width Modulation AC Chopper

FFT Analysis of Pulse Width Modulation AC Chopper is shown in Figure 9. It will show THD value and output current value for harmonic reduction. Here choosing the maximum frequency as a 1000 Hz and taking a fundamental frequency as a 50 Hz. In the FFT Analysis are drawn between the Magnitude (% of fundamental) and Harmonic order.

V. CONCLUSION

In this paper a harmonic reduction and voltage regulation based on intelligent technique for single phase PWM AC chopper has been analyzed. The optimal PWM switching angles are obtained by the proposed fuzzy logic controller with minimum total harmonic distortions. In addition, the simulation results are correlated to confirm the performance in terms of improving the power quality and power factor.

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