Modulation Techniques in Single Phase PWM Rectifier

Arpit Bohra
Dept. of Electrical Engineering
FCRIT,Vashi
Navi Mumbai, India

Divya Sajeesh
Dept. of Electrical Engineering
FCRIT,Vashi
Navi Mumbai, India

Chintan Patel
Dept. of Electrical Engineering
FCRIT,Vashi
Navi Mumbai, India

Michael Saldanha
Dept. of Electrical Engineering
FCRIT,Vashi
Navi Mumbai, India

ABSTRACT
This paper deals with the modulation techniques associated with the single phase pulse width modulated (PWM) rectifier. A PWM rectifier is obtained by replacing the diodes in a bridge rectifier with power electronic switches like MOSFET, IGBT etc. The ON/OFF instants of theses switches can be controlled to approximate input power factor to unity and reduce total harmonic distortion (THD) of input current. A MATLAB simulation of PWM rectifier using hysteresis current control technique is done using simulink and waveforms are analyzed for power factor, THD and ripple in output voltage.

Keywords
PWM, THD, power factor

1. INTRODUCTION
All electronic equipments require a stable, fixed and regulated DC voltage as power supply. So most of the electronic circuits use a diode rectifier or thyristor controlled rectifier circuit for DC supply. Such circuits uses a filter capacitor at the output for obtaining a smooth DC bus voltage which results in poor input power factor and high harmonics in the input current[1]. This is due to the reason that capacitor draws current only when it charges, making the input current peaky in nature. Poor power factor and high THD causes the heating of the line conductors [2], heating of core of transformers, reduction of available power [3] and increased value of rms current of rectifier input current, which reduces the rectifier efficiency. To keep good quality of the power, strict regulations are there on the harmonics that can be injected by any power electronic circuits in to the supply system. Since rectifier is an inevitable part of electronic circuits, improving power factor and decreasing THD of such circuits are possible by replacing the diode with IGBT or MOSFET, which are gaining much importance. Rectifier circuits with power electronic switches are known as PWM rectifier [4]. In addition to power factor improvement, they are capable of allowing the power flow bidirectional as well as output DC voltage can be regulated. This is possible by controlling the width of the pulses given to these switches. Various control techniques existing are sine triangular pulse width modulation (SPWM) and hysteresis current control. This paper analyses a hysteresis current control technique used **in PWM rectifier circuits.**

2. TOPOLOGY OF PWM RECTIFIER
PWM rectifier works in two quadrants of the voltage current plane. Hence it allows the flow of power in both directions. Fig.1 shows the circuit configuration of single phase PWM rectifier.

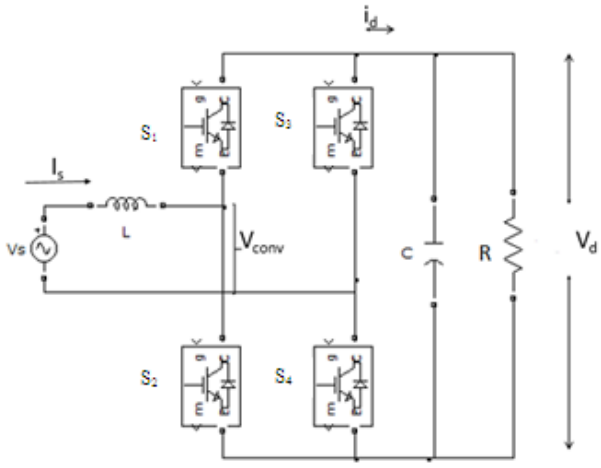

Fig. 1. Circuit of single phase PWM rectifier

It consists of four switches, inductor at input, and filter capacitor and load resistor at the output. The pulses given to the switches are modulated to control the power in the rectifier. Input inductor shapes the input current to a sinusoidal one and filter capacitor reduces ripple in the output voltage. The power flow in the rectifier is based on the phasor diagram given in Fig.2.

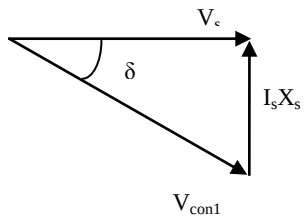

Fig.2. Phasor diagram for power flow

The fundamental of rectifier input voltage V_{conv1} lags the supply voltage V_s by an angle δ. By making δ leads the supply voltage, power can flow from DC to AC side. The main control required in PWM rectifier is to reduce THD, regulate the output voltage and shape the input current to sinusoidal and in phase with the supply voltage. Next section describes the various control techniques used in PWM rectifier.

3. PWM TECHNIQUES

The main aim of PWM technique in PWM rectifier is to control the amplitude of the harmonics present at the input side. The control scheme used in PWM rectifier is by comparing actual voltage with the reference voltage and the error is given to a PI controller. The output of the PI controller is multiplied by a sine template from the supply voltage. The output of product block gives the reference current that is to be drawn from the supply. The block diagram of the control scheme is given in Fig.3. This reference is given to a current controller to generate the PWM pulses.

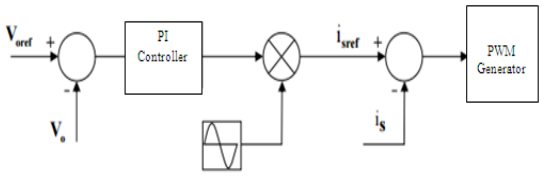

Fig. 3. Control scheme of PWM rectifier

The current controller can be SPWM or hysteresis current controller.

3.1 SPWM control

This is a carrier based modulation technique. In SPWM technique the reference current so obtained is phase shifted by an angle δ. This phase shifted reference wave is compared with a carrier wave of high frequency to generate the PWM pulses. Fig.4. shows pulse generation with triangular carrier wave

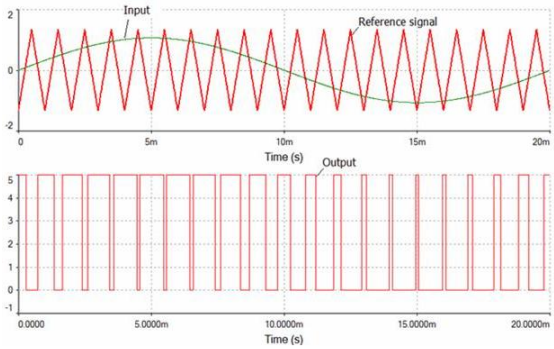

Fig.4. PWM generation using SPWM technique [5]

3.2. Hysterisis control

This method is based on the error between the reference output voltage and measured output voltage. The states of the elements are changed when ever, the instantaneous calculated error falls outside a predefined hysteresis band, which drives the error back into the hysteresis band [6]. In hysteresis current controller, the actual current is made to follow the reference current using a hysteresis current controller as shown in Fig.5.

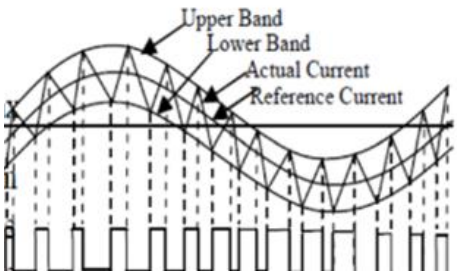

Fig. 5. PWM pulse generation by hysteresis control [6]

The output of the hysteresis controller gives the pulses to be given to switches to maintain the input current at par with the reference current. In this paper simulation based on hysteresis controller is done and results are given in next section.

4. SIMULATION RESULTS

The parameters used for the simulation is given in Table.1

Table.1 Parameters used in simulation

Parameters	Values
Input voltage	220V
Output voltage	400V
Input inductor	10mH
Output resistance	200Ω
Filter capacitor	1600μF

Based on the above parameters a MATLAB simulation using simulink was done. The power circuit of the PWM rectifier in simulink is shown in Fig.6

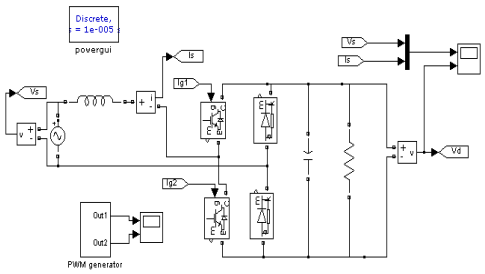

Fig.6. MATLAB model of PWM rectifier

In this model only two switches are used and remaining two are diodes. The control diagram of the pulse generation is shown in Fig.7.

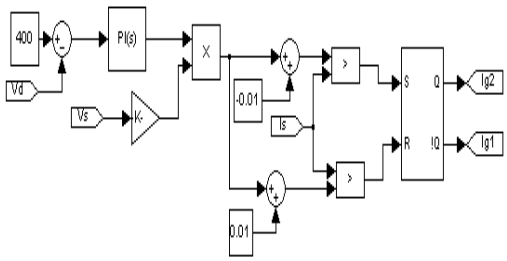

Fig. 7. Generation of gate pulses

Reference voltage is compared with actual output voltage and the error is given to a PI controller. This error voltage is multiplied with a sine template derived from supply voltage, which is the reference current. The actual input current is

made to follow this reference current within a hysteresis band of 0.02. After tuning the PI controller the circuit draws the required input current and the waveforms of input current and supply voltage so obtained are shown in Fig.8

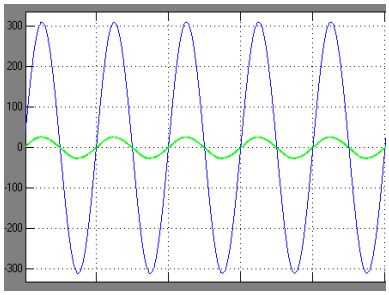

Fig. 8. Input voltage and current of the rectifier

Input current is sinusoidal and in phase with supply voltage making the displacement power factor unity. The DC output voltage of the circuit is given in Fig.9

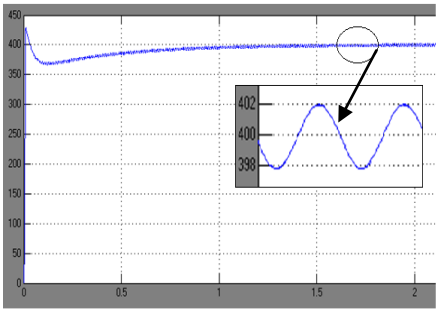

Fig. 9. Output voltage of PWM rectifier

Output voltage is regulated at 400V and it contains ripple of 4V peak to peak. The ripple is sinusoidal in nature with a frequency of twice the supply frequency. Fig.10. shows the frequency spectrum of input current.

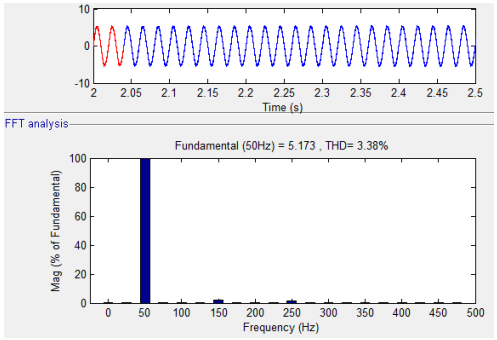

Fig. 10. Frequency spectrum of input current

Input current THD is 3.58% which is within the limit as given by the IEC standards [7]

5. CONCLUSION

This paper presents a PWM rectifier operated by hysteresis current control technique. By controlling the input current of rectifier using hysteresis technique, it is possible to bring the THD of input current within the limit. Also input current is in phase with supply voltage and hence power factor is unity. This circuit uses only two switches and two diodes which make the circuit a cost effective one. The future scope is that, circuit can be be further modified by replacing the diodes with switches and gate signals can be controlled to make the power flow from DC to AC side.

6. REFERENCES

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