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Power Quality Enhancement of DC Motor Drive Using Mulitple/Sinusoidal PWM Technique

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ABSTRACT

This paper presents the design and harmonic analysis of single phase PWM rectifier fed separately excited DC motor drives. The scope of this paper is to reduce the current harmonics at the input side of the PWM rectifier. A PWM based switching technique is proposed to reduce the harmonics. Single phase PWM rectifier and Single phase controlled rectifier comparison on the basis of the input current harmonic analysis is presented. The paper also presents a comparison with MATLAB simulation and experimental values. PWM control can be developed using FPGA controller. Simulation results are presented.

Keywords: PWM Rectifier, Field-Programmable Gate-Array, Harmonic Distortion

I. INTRODUCTION

Harmonics in power system have received increased attention in recent years with the widespread application of advanced solid-state power switching devices in a multitude of power electronic application. Traditional power rectifiers based on diodes and thyristors have been on the decline owing to their injection of significant amount of low order harmonic currents in to the power system, low displacement factor and the high ripple content in the dc-link voltage [1-3]. The phase control and the commutation of semiconductor devices impact on the phase displacement between the harmonics of consumed current. This displacement leads to power factor degradation and to reactive power consumption. The consumed current harmonics cause non-sinusoidal voltage drops on the supply network impedances [4].

To reduce these side effects the rectifiers are being supplemented by filters and compensators [12,15]. But the filters cannot be designed in a general way, but must be designed for a given application. Disadvantage of this method is that additional circuits raise the costs ant requirements on the material and spaces needed for the converter are increased [5-7].

With the advent of high power, inexpensive, fast switching devices, line commutated rectifiers have been gradually replaced by pulse width modulated (PWM) switch mode rectifiers [8-11,13,16-17]. For experimental setup the PWM gating signals are generated using FPGA based controller.

II. SINGLE PHASE PWM RECTIFIER

The PWM rectifier is an AC- DC power converter which is implemented using semiconductor devices such as MOSFETs, IGBTs that can be switched ON and OFF. The rectifier is controlled by pulse width modulation. Rectifier controlled in this way consumes current with demanded waveform that is mostly sinusoidal. It works with given phase displacement between consumed current and supply voltage, enables control of power factor, and has minimal effects on the supply network. Main features of PWM rectifiers are: bi-directional power flow, nearly sinusoidal input current, regulation of input power factor to unity, low harmonic distortion of line current (THD below 5 %), adjustment and stabilization of DC link voltage (or current), reduced capacitor (or inductor) size due to the continuous current. Furthermore, it can be properly operated under line voltage distortion and line frequency variation.

III. CIRCUIT CONFIGURATION

Figure 1 shows the schematic diagram of single phase PWM rectifier. It consists of 4 MOSFETs connected in full bridge and includes input inductance and output capacitor. Four diodes connected in series with each MOSFETS to avoid the freewheeling action of internal diodes present in the switches. This rectifier can work with two (bipolar PWM) levels. The possible combinations are:

- ✓ Switch M1 and M3 are in ON state and M2 and M4 are in OFF state.
- ✓ Switch M2 and M4 are in ON state and M1 and M3 are in OFF state.

The aim is to control the rectifier in such a way that it consumes harmonical current from supply network, which is in phase with the supply voltage. This can be achieved by controlling the rectifier in one of a number of ways, e.g., by pulse width modulation techniques. In this paper both multiple and sinusoidal Pulse Width Modulation techniques are used, in which both the techniques are shown in the figure 2 and figure 3 respectively.

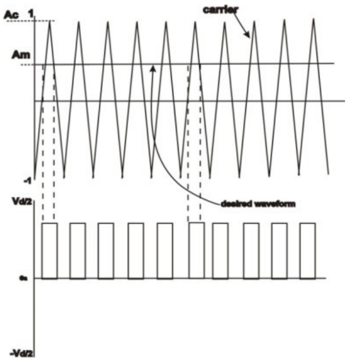

Figure 2. MultiplePulseWidth Modulation technique

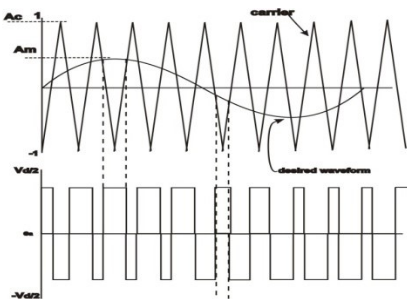

Figure 3. Sinusoidal Pulse Width Modulation Technique

IV. TOTALHORMONIC DISTORTION

The THD is defined as the root mean square (RMS) value of the total harmonics of the signal, divided by the RMS value of its fundamental signal. For currents, the THD is defined as

$$THD = \frac{I_H}{I_F}$$

Where

$$I_H = \sqrt{I_2{}^2 + I_3{}^2 + \cdots + I_n^2}$$

I_n : RMS value of the Harmonic n

I_F : RMS value of the fundamental current

V. HARDWARE IMPLEMENTATION

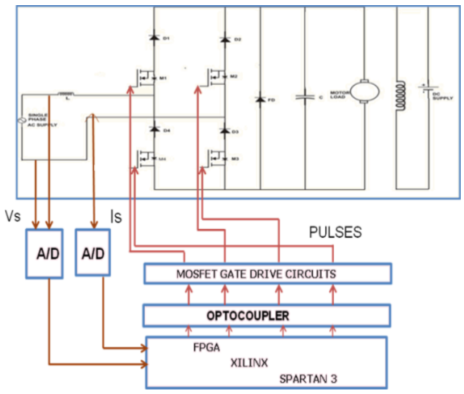

Figure 4. Hardware implementation for single phase PWM rectifier

The circuitry of the proposed PWM controller is shown in figure 4. Usually, for digital control of power circuits, isolation of digital circuit from power circuits as well as the amplification of firing signals are essential. Therefore, a driver circuit is incorporated here to deliver the control pulses to the power circuit and to achieve the complete isolation. Optocoupler is used to shift the voltage level from 5V to 15V. Also the optopcoupler provides electrical isolation. This voltage level helps the driver circuit to work since the driver circuit supply ranges from 10V to 20V.

VI. INTRODUCTION TO FPGA

The hardware implementation of digital controller for PWM rectifier is normally carried out by using a microcontroller or DSP which is responsible for the fulfillment of control tasks and generation of pulses. Although microcontroller-based systems provide advantages such as flexibility and reliability, they tend to become computationally inadequate in certain demanding applications. This problem can be overcome by using FPGA as a controller. Figure 5 . Shows the block diagram of power electronic system.

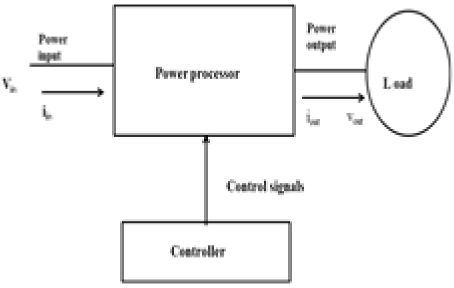

Figure 9. Control Block Diagram

An FPGA is a regular structure of logic cells (modules) and interconnect, which is under the designer's complete control. FPGAs are programmed using support software and a download cable connected to a host computer. FPGA consists of three major configurable elements: Configurable Logic Blocks (CLBs), Input-Output Blocks (IOBs), Programmable Interconnects. The design functionality is described either by using schematic editors of by using one of the various Hardware Description Languages (HDLs) like Verilog or VHDL.

VII. SIMULATION RESULTS

The toolbox MATLAB/SIMULINK is used to simulate the system, by which various results are obtained .The experimental work, is going on by using field-programmable gate-array (FPGA)- based digital controller**.** The simulation model and gating pulse generation for single phase PWM rectifier are shown in the figure 6 & figure 7 respectively.

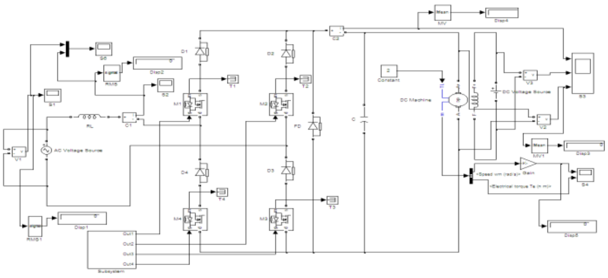

Figure 6. Simulation Model

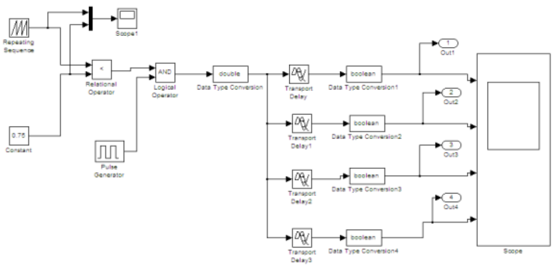

Figure 7. Control circuit

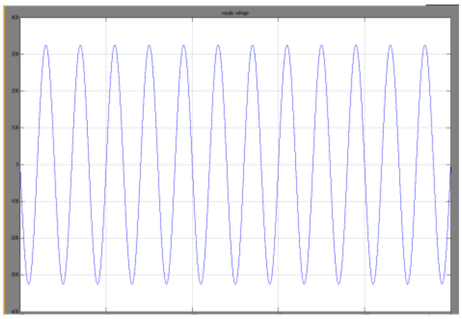

Figure 8. Supply Current

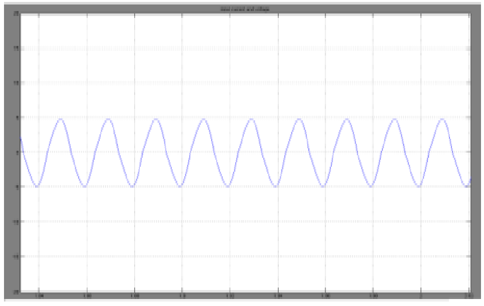

Figure 9. Supply Voltage

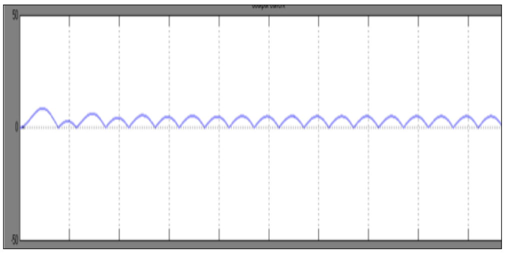

Figure 10. Output voltage

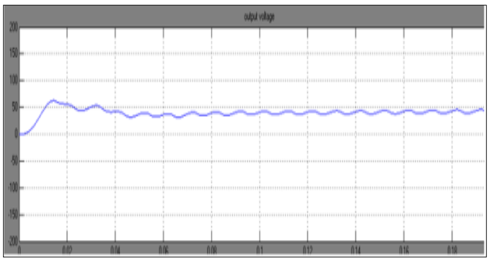

Figure 11. Output current

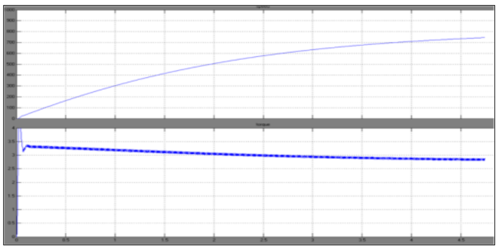

Figure 12. Speed and torque

A motor load is connected at the output through an *L–C* filter. The values of the filter used are L = 200 mH, and C = 1000 µF. Figure 8 shows the waveform of supply voltage and current. Figure 9 shows the waveform of output voltage and current. Figure 10. shows the waveform of speed and torque. The THD for phase controlled rectifier and PWM rectifier shown in Fig 11, 12, 13.

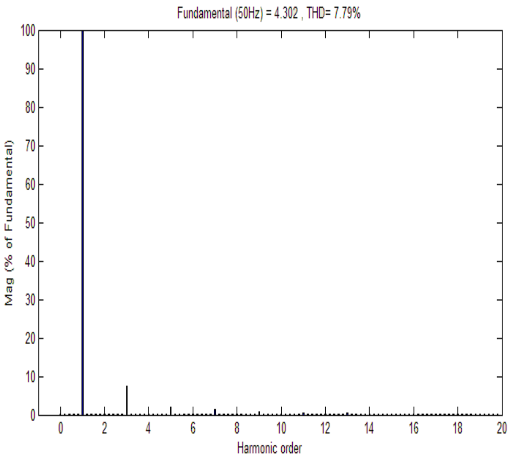

Figure 13. THD for PWM rectifier with MPWM

Furthermore, the input frequency is observed to vary between 48.8–50 Hz, while the converter switching sequence is done assuming a constant supply frequency of 50 Hz.In order to compare the performance of the PWM rectifier with phase controlled Rectifier, the THD of PWM rectifier and controlled rectifier is presented here Table 1.

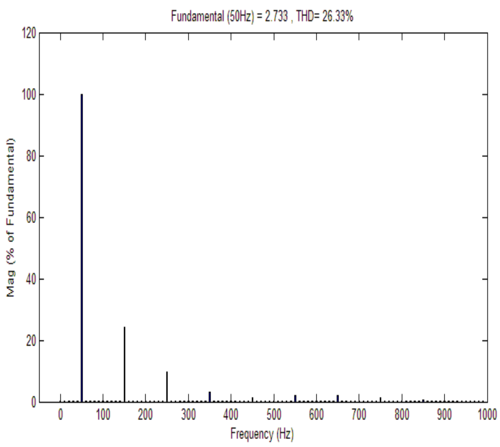

Figure 14. THD for controlled rectifier

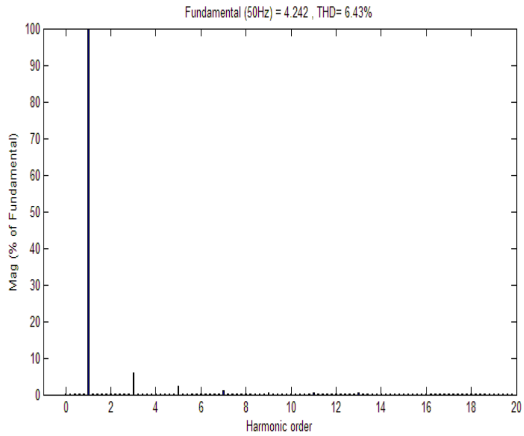

Figure 15. THD for PWM rectifier with SPWM

SL.NO	PWM RECTFIER								CONTROLLED RECTIFIER			
	MPWM				SPWM				FIRING ANGLE			
	NO.OF PULSES	OUTPUT VOLTAGE	THD	SPEED	NO.OF PULSES	OUTPUT VOLTAGE	THD	SPEED	α	OUTPUT VOLTAGE	THD	SPEED
1	3	123.4	7.83%	844	3	113.1	6.42%	753	75°	122.3	20.66%	931.5
2	5	123.4	7.79%	843.4	5	112.9	6.45%	751.8	80°	111.8	21.96%	835.6
3	7	123.3	7.75%	842.3	7	113	6.46%	752.1	95°	66.18	26.38%	439.1

Table 1. Comparision of THD for PWM Rectifier and Controlled Rectifier

VIII. CONCLUSION

The use of PWM control in rectifiers eliminates the problems caused by using phase controlled rectifiers. Thus the PWM rectifiers can perform well in many applications such as battery charger, UPS system, regulated DC voltage source. The PWM rectifier can assert itself for its good behavior in many applications, for example as an active filter, or as an input rectifier for indirect frequency converter. The thyristor rectifiers due to their phase control load supply grid with higher harmonics and consume reactive power. These effects of phase control cannot be ignored and must be suppressed or compensated. The modern way is to apply the rectifier with pulse width modulation instead of the thyristor rectifier. The high switching frequency required in the control scheme has made the input filtering of the ac current harmonics easier. The size of the smoothing capacitor at the dc side can also be reduced due to reduction of the harmonic content in the dc voltage. All these size reductions make the goal of miniaturization of the rectifier circuit within easy reach. Both rectifiers were tested under the same conditions and the simulations results have shown that total harmonic distortion have greatly reduced by using pulse width modulation techniques.

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