

Experimental Study and Analysis of Harmonics Generation in Uncontrolled and Controlled Rectifier Converters

Aslam P. Memon, Ahsan Zafar, M. Usman Keerio, Waqar Ahmad Adil, Asif Ali. A

*Department of Electrical Engineering,
Quaid-a-Awam University of Engineering Science & Technology, Nawabshah, Sindh, Pakistan*

Abstract: Experimental studies of power converters rectifiers, their performance with different loads and their analysis is included in this research. These results are laboratory based in which controlled and uncontrolled rectification (FW, 1- ϕ & 3- ϕ) are observed with different loads (R, R-L) with their output rectified waveforms. Software models are developed, bases on the attained parameters in order to compare their precision with laboratory models and the final harmonics and total harmonic distortion produced by the power rectifier converters due to non linear loads are concluded.

Key words: Rectifier, Thyristor, Matlab, Simulation, FFT

INTRODUCTION

Rectification circuit is the primitive Power Electronics circuit which transforms AC into DC and also used in many fields. Simulation with modeling is often used to analyze the working process of the rectification. Working theory of rectification circuit and the harmonic components can be studied more deeply on the basis of analysis and conclusion of the simulation results. Analysis of the target, in this paper is done by single phase and three phase full wave uncontrolled and controlled rectification circuit and been modeled practically and also by MATLAB/SIMULINK. Then harmonics of AC side current and waveforms are analyzed with these models.

Experimental & Simulink Analysis

First the Rectifier Models are made practically in the Power Electronics lab using the 70-002 Thyristor Control Panel of Feedback Company. And after that same models are simulated in Matlab using the same parameters which are used in practical trainer. Fig. 1(a) shows the 70-002 Thyristor Control Panel. By using this panel all the uncontrolled and controlled rectifiers are performed. The trainer includes the different components whose ratings are given below in table 1.

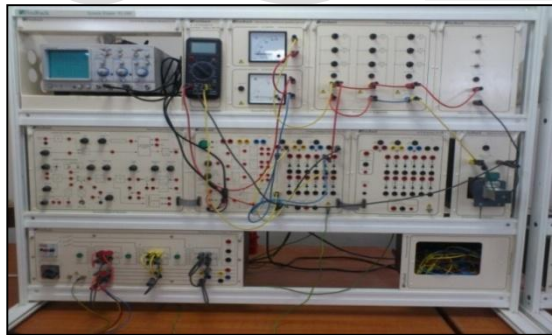


Fig. 1: 70-002 Thyristor Control Panel

Table 1: System Components

Equipment	Ratings
1- ϕ voltage	200V ac
3- ϕ voltage Phase-to-phase	173V ac
3- ϕ voltage Phase-to-ground	100Vac
Inductive load	700mH
Resistive Load	182 Ω
Frequency	50 Hz
Oscilloscope, Moving iron voltmeter/ammeter (mean values) Multimeter (rms values)	

Single phase full wave uncontrolled rectifier

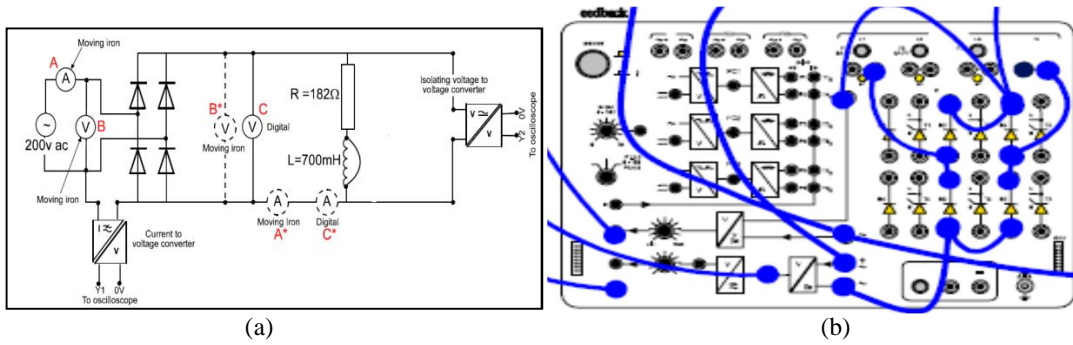


Fig. 2: (a) Circuit diagram of Single phase full wave uncontrolled rectifier (b) Patching diagram for single phase full wave uncontrolled rectifier

During the positive phase of the supply voltage cycle current flows from the supply positive through D1, through the load and returns to the supply negative through D3. During the negative phase of the supply voltage cycle current flows from the supply positive through D2, through the load and returns to the supply negative through D4. At 180° commutation or switching occurs and the conducting diode pairs switch from D3 and D2, to D1 and D4.

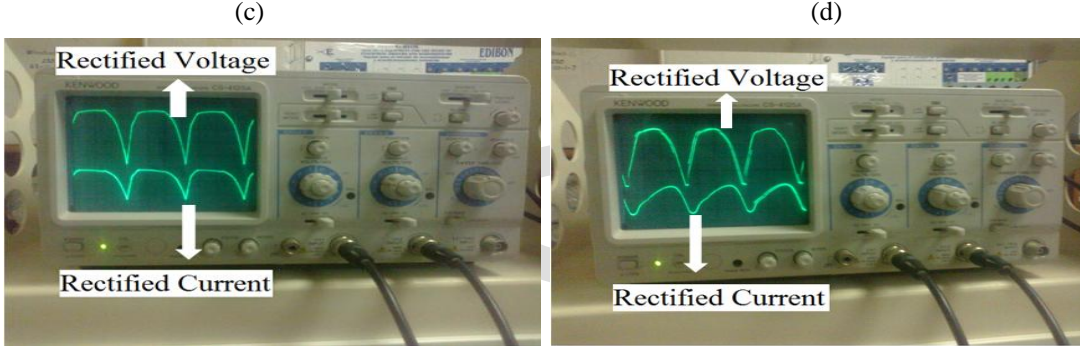


Fig. 2: (c) Waveforms of rectified voltage & Current with resistive load (d) Waveforms of rectified voltage & Current with resistive inductive load

It should be now clear that the diodes are acting as switches, synchronized to the supply, which turn on and off so as to make the current through the load always positive. The voltage waveform is not smooth as it ranges from zero to its maximum value twice during each main supply cycle, in a discontinuous manner at each commutation point. This gives rise to harmonics which are propagated back to the supply, since the “primary” supply transformer winding may also be regarded as a “secondary” winding when considering changing voltages in the secondary. These harmonics may exceed those permitted by the Public Electricity Supply Authority.

Now the third step which is the simulation of this model in the Matlab.

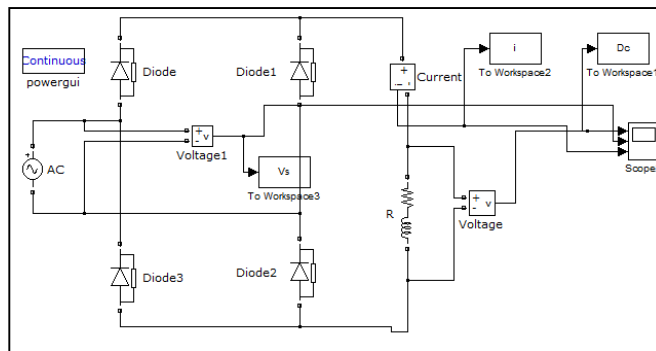


Fig. 2: (e) Simulink model of single phase full wave uncontrolled rectifier with resistive inductive load

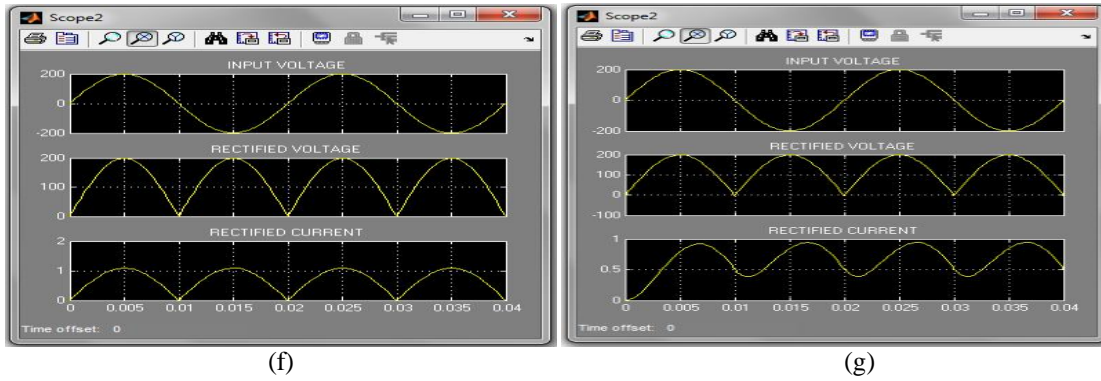


Fig. 2: (f) Waveforms of Rectified voltage & current across Resistive load (g) Waveforms of Rectified voltage & current across Resistive inductive load

Now the Harmonic analysis of this rectifier using FFT tool of Power GUI of Matlab is performed.

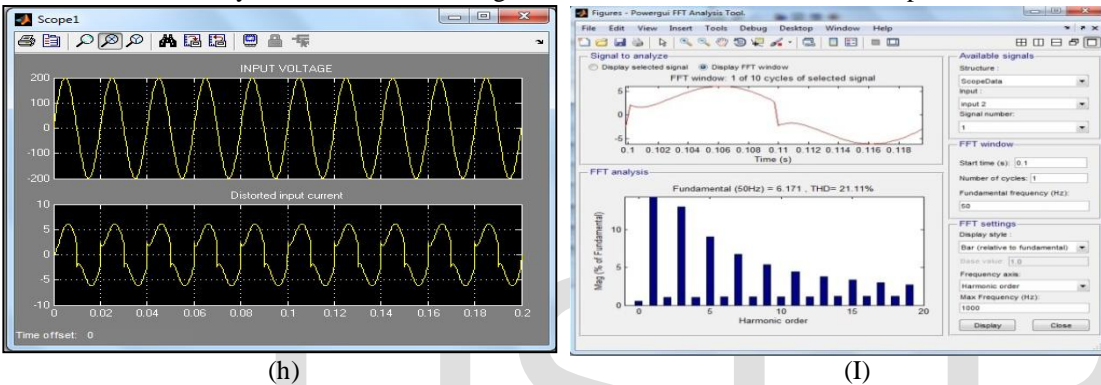


Fig. 2: (h) Input current and voltage waveform distorted by harmonics (I) Input current harmonics

Total Harmonic Distortion = 21.11%

Three phase full wave uncontrolled rectifier

The same Procedure by practically and by software means is repeated with this rectifier.

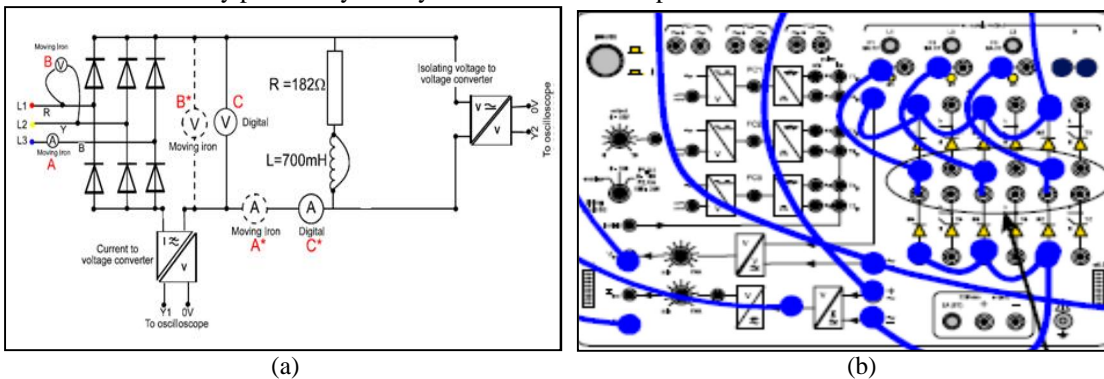
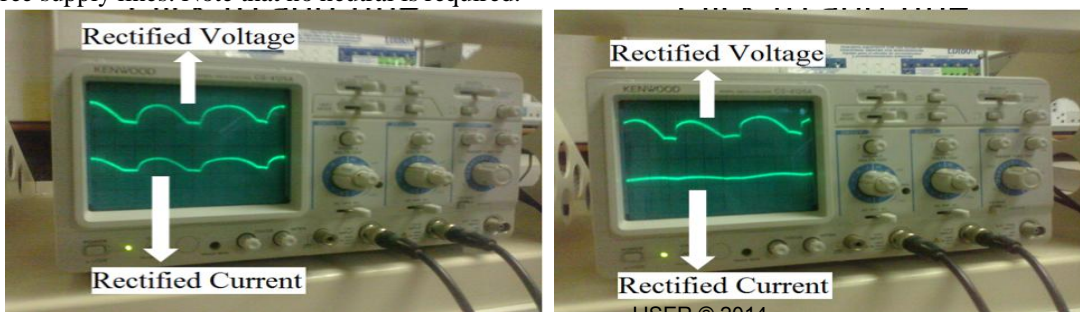


Fig. 3: (a) Circuit diagram of three phase full wave uncontrolled rectifier (b) Patching diagram of three phase full wave uncontrolled rectifier

The load is fed via a three phase half wave connection, the return current path being via another half wave connection to one of the three supply lines. Note that no neutral is required.



(c)
 (d)
Fig. 3: (c) Waveforms of rectified voltage & Current across resistive load (d) Waveforms of rectified

voltage & current across resistive inductive load

Now the Matlab based Simulink model of three phase full wave uncontrolled rectifier

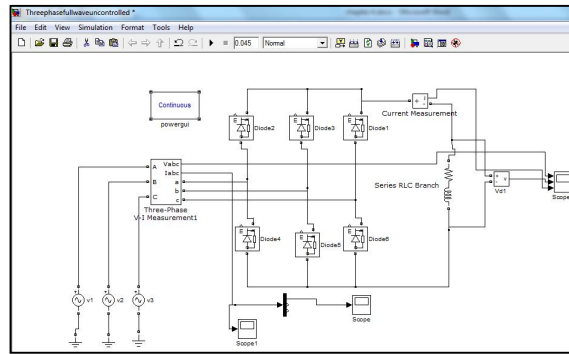
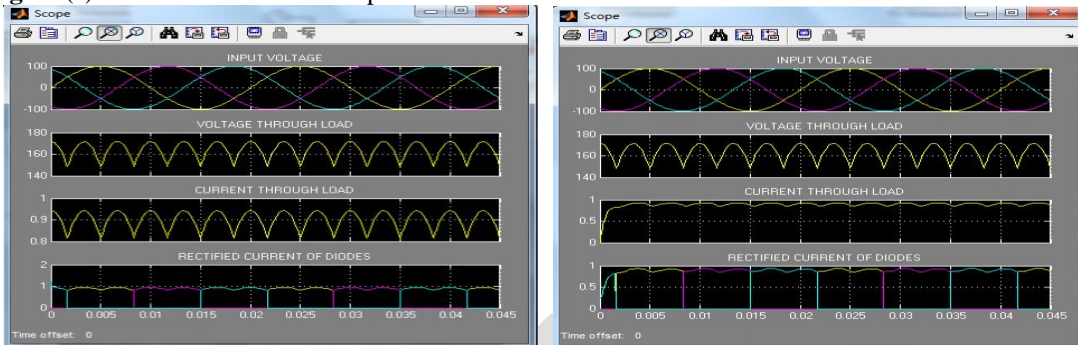


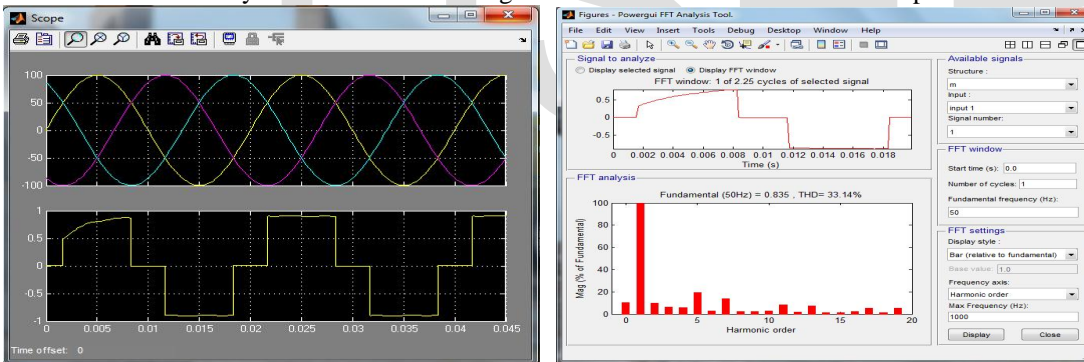
Fig. 3: (e) Simulink model of three phase full wave uncontrolled rectifier with resistive and resistive inductive load



(f)

(g)

Fig. 3: (g) waveforms of rectified voltage & current with resistive load (h) Rectified waveforms of current and voltage with R-L load
 Now the Harmonic analysis of this rectifier using FFT tool of Power GUI of Matlab is performed.

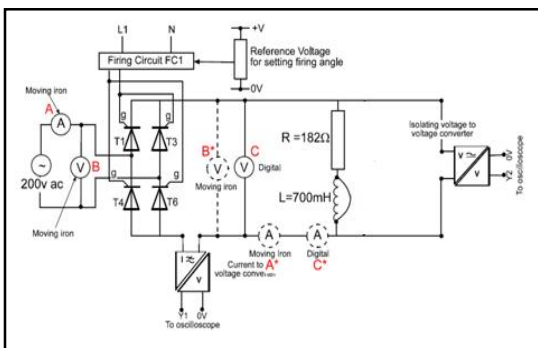


(h)

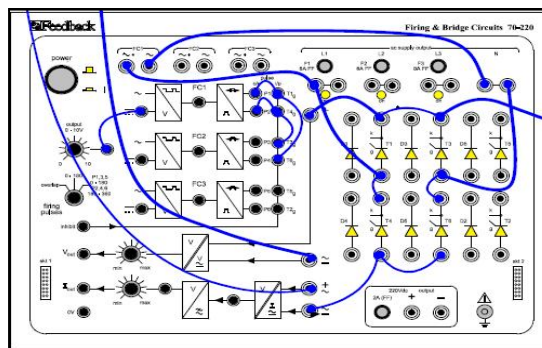
(I)

Fig. 3: (I) Input voltage and current waveforms distorted due to harmonics (j) Input current harmonics
Total Harmonic distortion = 33.41%

Single phase full wave controlled rectifier



(a)



(b)

Fig. 4: (a) Circuit diagram single phase full wave controlled rectifier (b) Patching diagram single phase full wave controlled rectifier

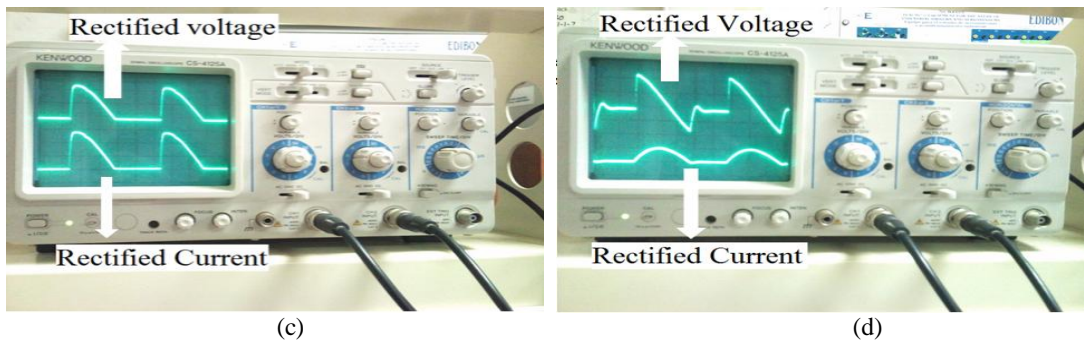


Fig. 4: (c) Rectified voltage & current with resistive load (d) Rectified voltage & current with resistive inductive load

Now the Matlab based Simulink model of Single phase full wave controlled rectifier

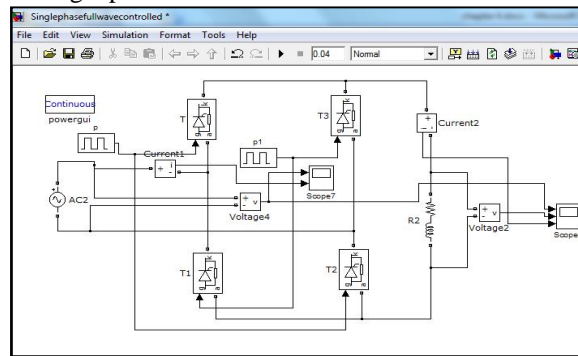
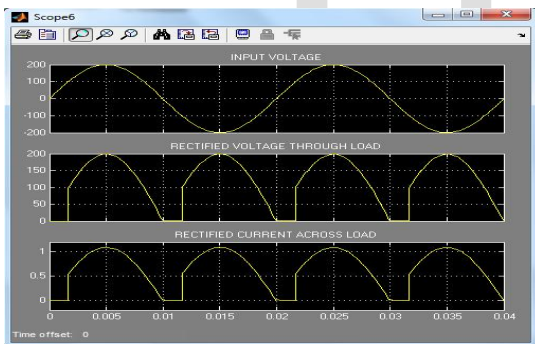
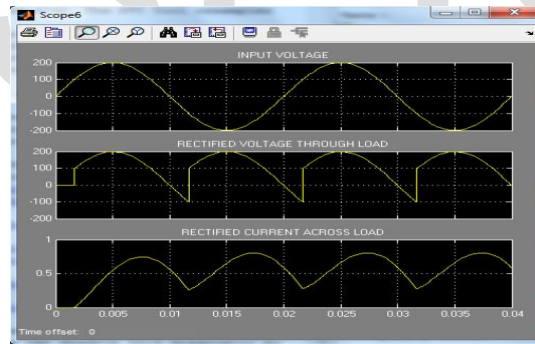


Fig. 4: (e) Simulink model of single phase full wave controlled rectifier with resistive and resistive inductive load



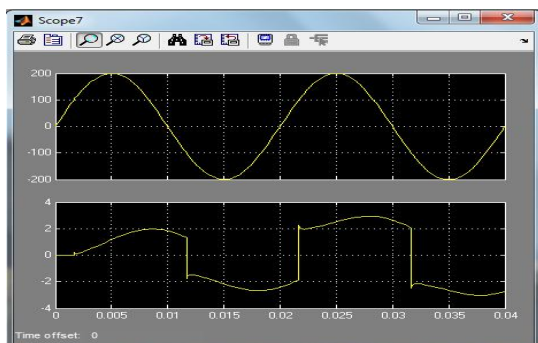
(f)



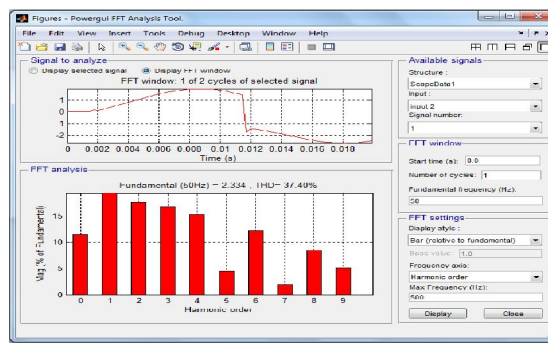
(g)

Fig. 4: (f) Rectified voltage & current with resistive load (g) Rectified voltage & current with resistive inductive load

Now the Harmonic analysis of this rectifier using FFT tool of Power GUI of Matlab is performed.



(h)



(I)

Fig. 4: (h) Input Current and Voltage waveform distorted by Harmonics (I) Input Current Harmonics

Total Harmonics Distortion = 37.40%

Three Phase full wave Controlled Rectifier

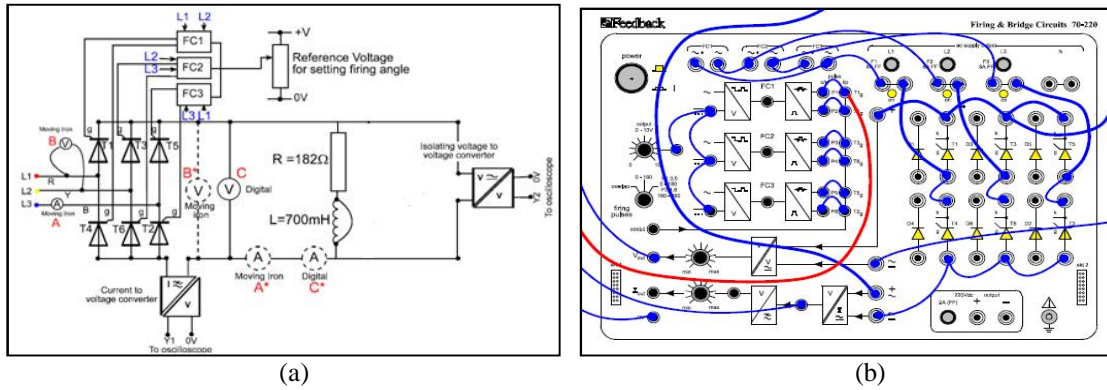


Fig. 5: (a) Circuit diagram of three phase full wave controlled rectifier (b) Patching Diagram

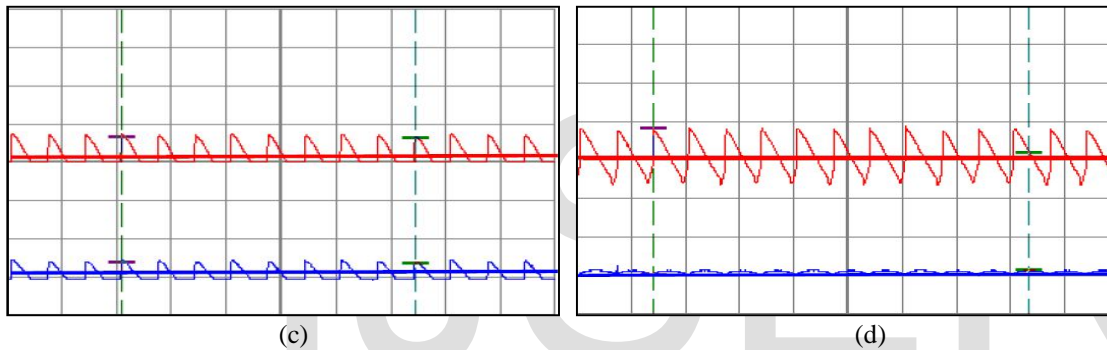


Fig. 5: (c) Waveform of rectified Voltage (red) & Current (blue) with resistive load (d) Waveform of rectified Voltage (red) & Current (blue) with resistive inductive load

Now the Matlab based Simulink model of three phase full wave uncontrolled rectifier

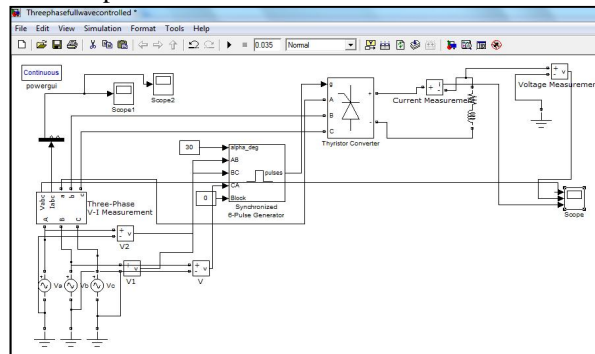


Fig. 5: (e) Simulink model of three phase full wave controlled rectifier with resistive inductive load

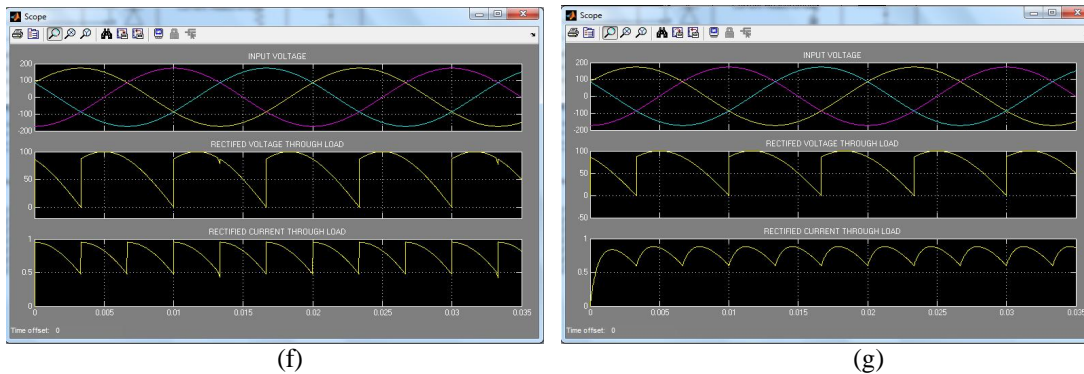


Fig. 5: (f) Waveform of rectified Voltage & Current with resistive load (g) Waveform of rectified Voltage & current with resistive inductive load

Now the Harmonic analysis of this rectifier using FFT tool of Power GUI of Matlab is performed.

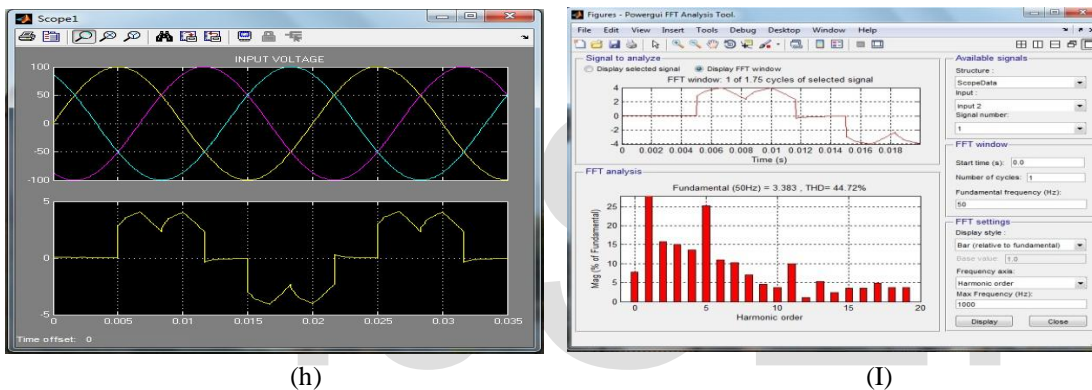


Fig. 5: (h) Input Voltage and Current waveforms distorted due to harmonics (I) Input current harmonics

Total Harmonic Distortion = 44.72%

Conclusion

The advantage of full wave rectification is that it is possible to draw a higher load current for a given rating of the supply transformer than is the case for half wave rectification. Harmonic analyzer is very costly equipment to find harmonics across any converter so in this research a Matlab based Simulink model is proposed to check harmonics of any converter by giving the practical data. Power rating of single-phase rectifiers tends to be lower than 10 kW. Three-phase bridge rectifiers are used for delivering higher power output, up to 500 kW at 500 V dc or even more.

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