academicJournals

Vol. 8(35), pp. 1753-1760, 23 September, 2013
DOI: 10.5897/IJPS2013.3954
ISSN 1992 - 1950 © 2013 Academic Journals
http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

Performance analysis of a Ĉuk regulator applying variable switching frequency

Md. Nazmul Hasan[1]*, Md. Shamimul Haque Choudhury[1,2], M. Shafiul Alam[1,2] and Muhammad Athar Uddin[1,2]

[1]International Islamic University Chittagong (Dhaka Campus), 147, Green road, Dhaka-1205, Bangladesh.
[2]Bangladesh University of Engineering and Technology, Bangladesh.

Accepted 09 September, 2013

This paper examines the performance of Ĉuk regulator to convert three phase alternating current (ac) to direct current (dc). Firstly, three phase ac is rectified with bridge diode. The rectified dc voltage is applied to input of a Ĉuk regulator. Three phase harmonics filter is introduced at the input of the diode rectifier to improve the shape of the input current. The main technique applied here to improve the performance of the regulator is a variable switching frequency which is applied to the gate of the IGBT; that is, at different duty cycle of the regulator, the switching frequency is different. The Total Harmonics Distortion (THD) of the input current and the efficiency of the regulator are observed. The results shown here are simulated with Pspise.

Key words: Ĉuk regulator, Total Harmonics Distortion (THD), duty cycle.

INTRODUCTION

The demand of high quality power is increasing day by day in both commercial and industrial purpose. A great amount of work has already been done concerning the three-phase pulse width modulation (PWM) boost rectifier (Ooi et al., 1985; Wu et al., 1988; Wu et al., 1991; Habetler, 1993; Blasko and Kaura, 1997) and the buck rectifier (Kataoka et al., 1979; Busse and Holtz, 1982; Wiechmann et al., 1984; Ziogas et al., 1985). The disadvantage of these buck rectifiers is not being capable of providing more voltage than the input voltage. Another technique is boost type, which have the limitation of not being capable of providing output voltage lower than the input voltage. To overcome this limitation, a three phase PWM buck-boost rectifiers has been proposed in (Kikuch and Thomas, 2002). High order harmonic control analysis has been done. Combination of rectification and inversion function increases the complexity of operation and control of the scheme. Pulse generation is difficult because it is divided into three classes which increase difficulty of implementation. But, simplicity is a high consideration to design a regulator. Moreover, input current was found very high and no analysis has been reported to reduce the input current. A Ĉuk regulator was also proposed (Ruma, 2008) to improve the quality of the input current. This allows both steps up and step down control of rectifier output voltage. However, the study did not provide solution to input currents worsening shape with voltage control by duty cycle change. A switch mode regulator based on Ĉuk principle has been presented in (Alomgir, 2005) to regulate ac voltage to a desired value irrespective of the input voltage and load. But the efficiency was poor and no analysis has been done to improve input current. An improved voltage regulator and three phase rectifier based on boost topology are proposed in (Ahmed, 2006; Abedin et al., 2006) respectively. Ahmed (2006) has the problem of low

*Corresponding author. E-mail: nzml_hasan@yahoo.com, Tel: +8801670931619.

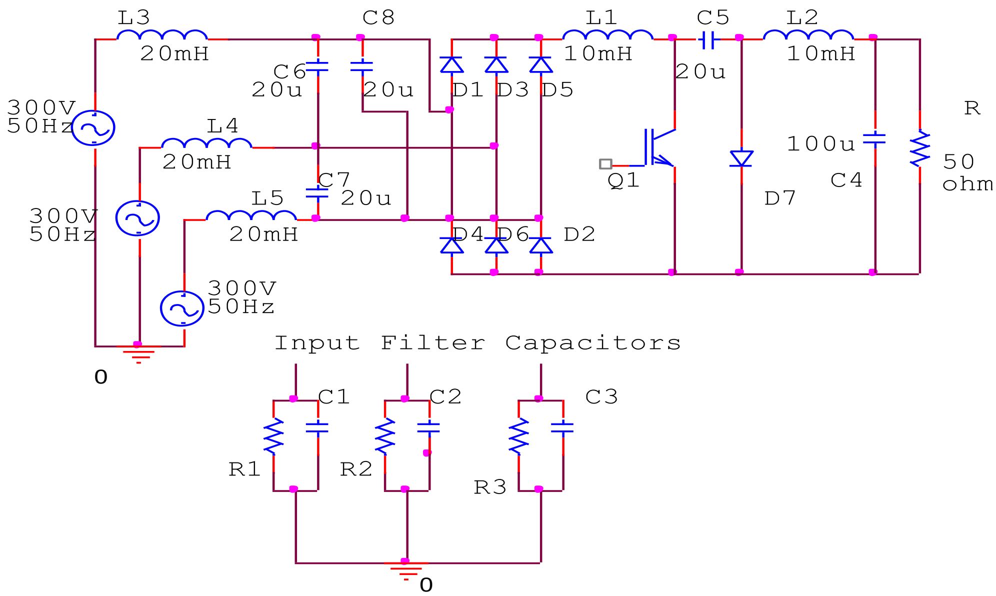

Figure 1. Circuit diagram of three phase Ĉuk rectifier with passive input filter and variable carrier frequency.

efficiency and Abedin et al. (2006) is not practically implementable due to large voltage drop across filters. The main objectives of this research work are (a) to propose a new control strategy to improve the performance of a Ĉuk regulator, (b) to simulate and study the new scheme under proposed control strategy for input current improvement of three phase diode rectifier, (c) total design of the input filter to reduce total harmonics distortion (THD) and hence reduce the input current of the converter, and (d) to increase the overall efficiency of the converter.

PROPOSED ĈUK REGULATOR

A Ĉuk regulator was investigated here to improve the overall performance to overcome the limitation of the fixed output voltage. A new strategy was introduced into the work. To avoid wide range of harmonics at the input current, the variable frequency control scheme was applied here by which the harmonics at the input current was limited within a certain range for all duty cycle (Figure 1). It is expected that the study will yield a three phase rectifier with improved power quality which is practically implementable for medium power application.

RESULTS AND DISCUSSION

The shape of the input current indicates that the performance of the regulator was improved. The simulated input current with 60% duty cycle is shown in Figure 8. Distortion free sinusoidal input current is a major consideration in a rectifier design. Many techniques have been developed by researchers in previous works. But large input filter and complex control strategy was the limitation for practically implementing of these regulators. Another important thing is, regulated output voltage both below and above the input voltages are required in many cases. Only Ĉuk and Buck-Boost regulators are able to supply regulated voltage below and above the input voltage. In this paper, a Ĉuk regulator is proposed for improvement of input current and efficiency of a three phase rectifier. At first a three phase full wave diode rectifier has been studied. The input current was found non sinusoidal pulsating and THD was found 25%. A passive filter was introduced to improve the performance of the rectifier. THD was improved to 2% and the efficiency was improved to 94%. But input for this performance 100uf input capacitor is required which is very large and also draw high input current. As a result, the VA rating of the rectifier increases and weight becomes large. The output voltage was not controllable.

To overcome the problems, a Ĉuk regulated three phase rectifier has been studied without input filter. It was observed that the input current was highly distorted with large THD, though the efficiency was good. The output voltage is controllable. To improve the shape of input current of Ĉuk regulated three phase rectifier with passive input filter was studied. The switching frequency was kept constant. It was found from the analysis that the THD has improved for many of the duty cycles, but the overall efficiency of the regulator was not acceptable at all duty cycles. It was also observed that efficiency and THD cannot be kept at the desired level simultaneously with change in duty cycle.

To improve the overall efficiency and to maintain the

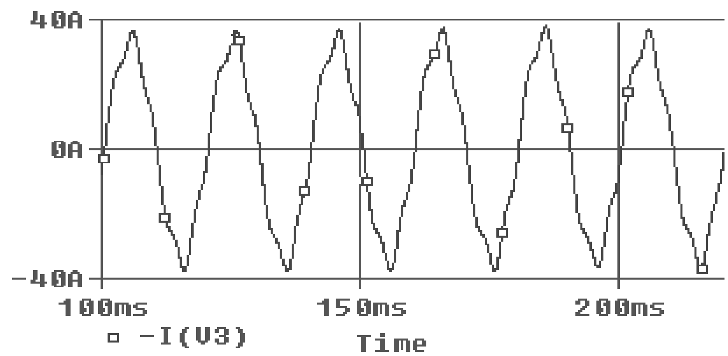

Figure 2. Input current of Ĉuk regulated three phase rectifier with passive input filter (duty cycle=60% and switching frequency= 2kz).

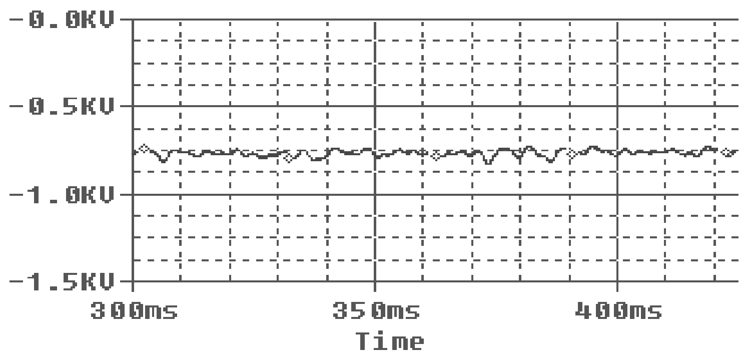

Figure 3. Output voltage of Ĉuk regulated three phase rectifier with passive input filter.

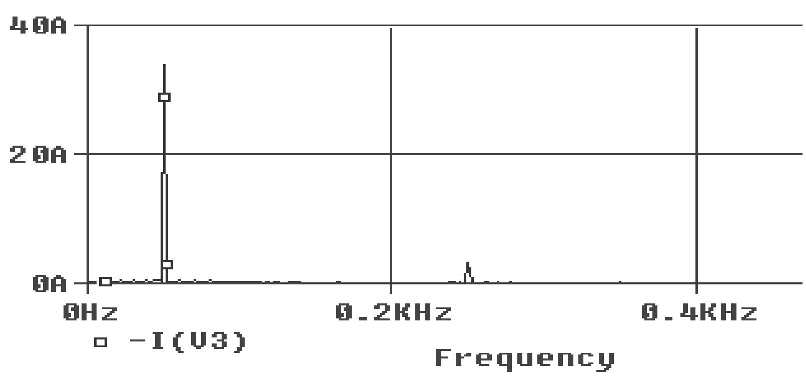

Figure 4. Typical FFT of input current of a Ĉuk regulated three phase rectifier.

THD of the input current at acceptable limit, a new topology was proposed and studied. A mixed passive filter was introduced at the input side of a Ĉuk regulator. At the same time, the switching frequency was varied from low to high frequency together with the variation duty cycles. It was found that highest THD was 7.533461% for 60% duty cycle which is below the tolerance level. The output voltage was varied from 187 volts to 770 volts with equal or more than 80% efficiency at all duty cycle. The value of input current was also acceptably low.

Input current, output voltage, FFT of input current, efficiency and power factor of the proposed Ĉuk regulator are shown in Figures 2 to 6 respectively. The overall performance of the proposed Ĉuk regulator can be understood in Table 1. The duty cycle versus power

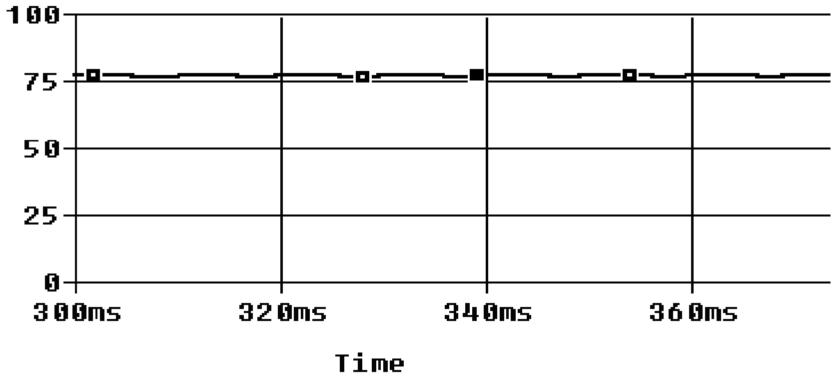

Figure 5. Efficiency of a Ĉuk regulated three phase rectifier.

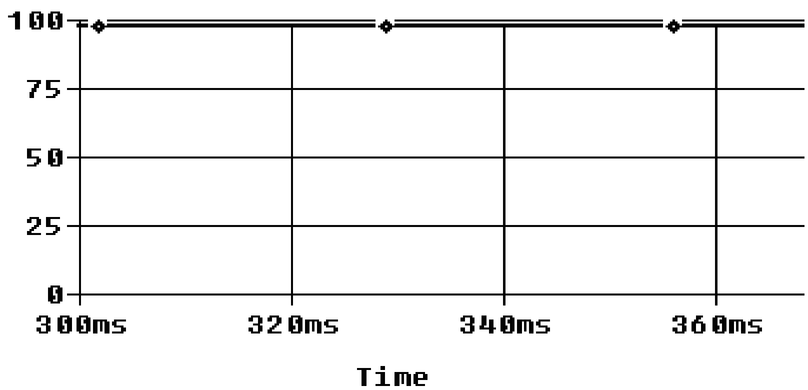

Figure 6. Power factor of Ĉuk regulated three phase rectifier with passive input filter.

Table 1. Performance parameter of Ĉuk regulator.

Duty cycle(%)	Frequency (KHz)	Input voltage (Volt)	THD (%)	PF (%)	Efficiency (η)%	Output voltage (Volt)
10	.75	300	3.144534E+00	21	82	187
20	1	300	5.868050E+00	47	94	310
30	1.25	300	5.265780E+00	65	99	400
40	1.5	300	5.247629E+00	76	92	460
50	1.75	300	7.149165E+00	91	91	600
60	2.00	300	7.533461E+00	98	80	770

factor, efficiency, output voltage, THD and switching frequency are shown in Figures 7 to 11.

Control strategy

A microcontroller based control system was introduced here. PWM modulation technique is applied to vary the duty cycle. Different duty cycles at different frequency have been generated by the microcontroller based circuit system. Practically generated pulse and flow chat of the program for generating pulse is given in Figures 12 and 13 respectively.

Conclusion

Three-phase PWM Ĉuk rectifiers have been investigated

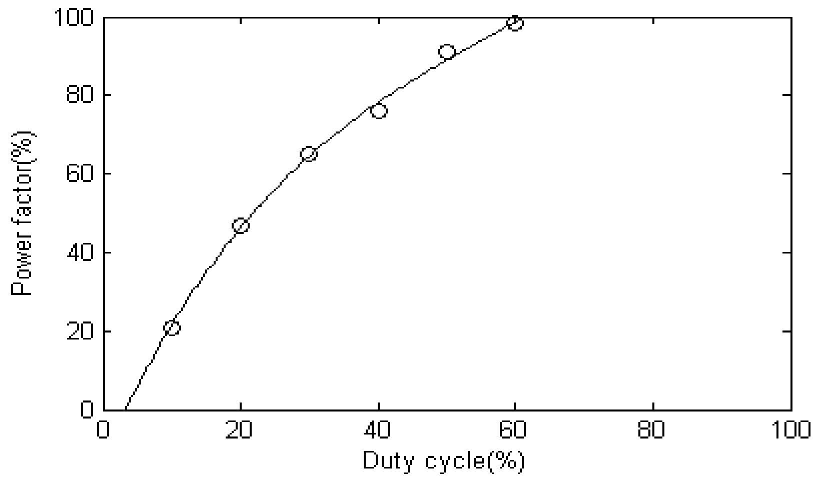

Figure 7. Duty cycle versus power factor.

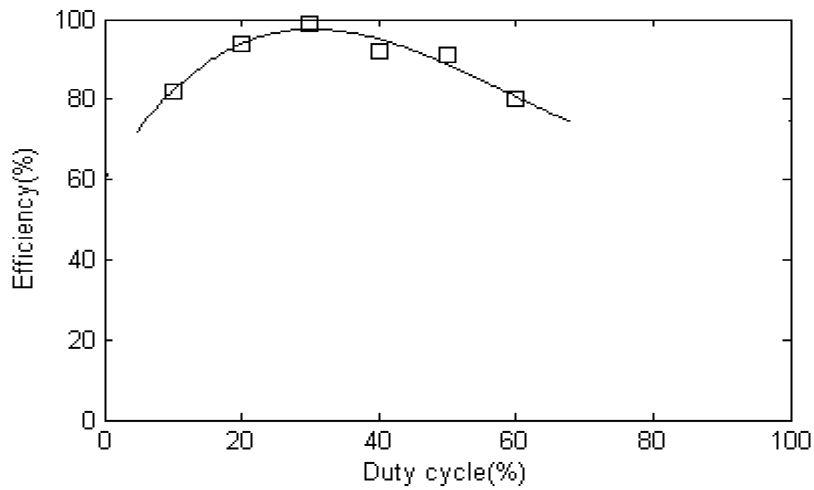

Figure 8. Duty cycle versus efficiency.

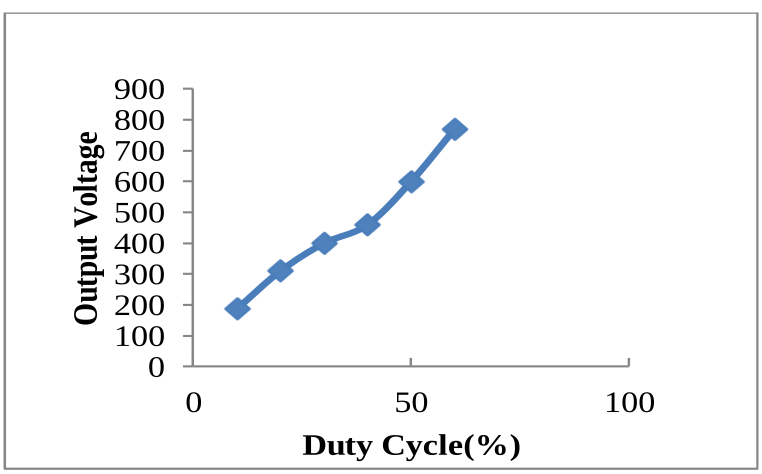

Figure 9. Duty cycle versus output voltage.

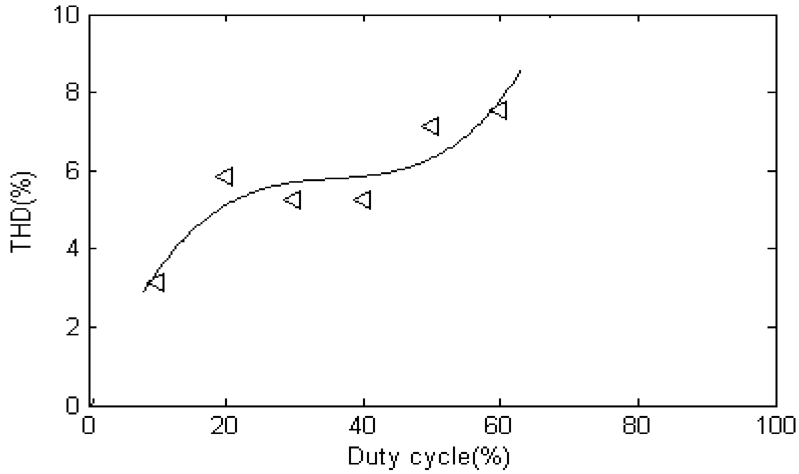

Figure 10. Duty cycle versus THD (%).

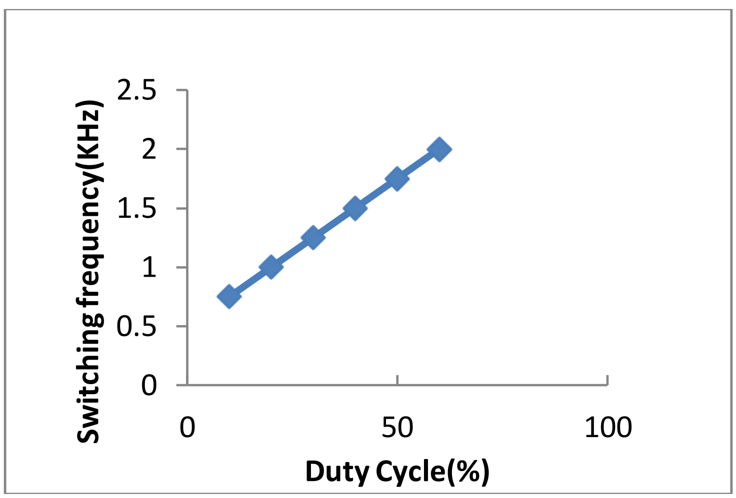

Figure 11. Duty cycle versus switching frequency.

Figure 12. Microcontroller generated pulse.

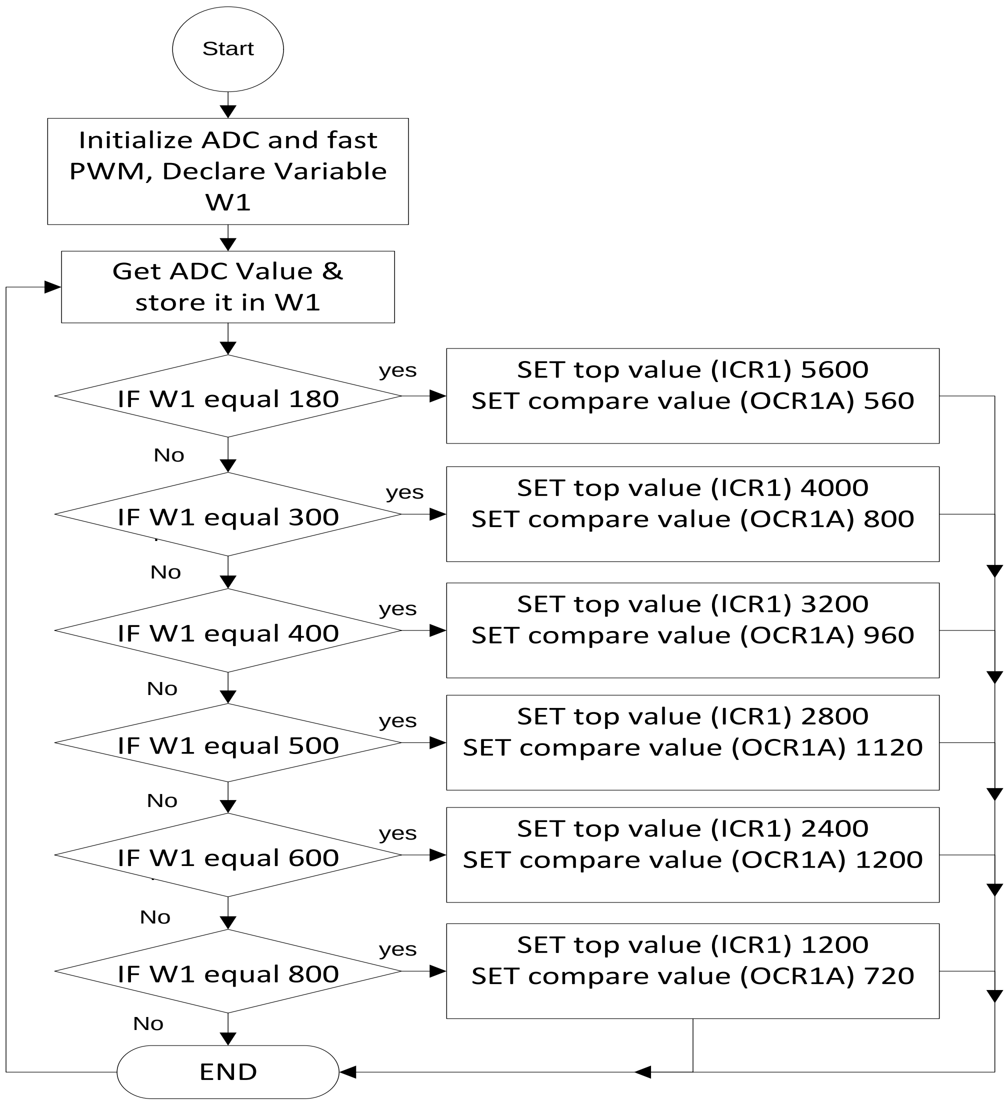

Figure 13. Flow chat of the program for generating pulse.

in this paper. The converters of interest have the properties of:

(1) Capabling both voltage step-up and step-down.
(2) Efficiency over 80% at all duty cycle.
(3) Almost sinusoidal input current. The simulated results have been presented here.

ACKNOWLEDGEMENTS

The authors acknowledge gratefully the support and facilities extended by the International Islamic University Chittagong (Dhaka Campus) and Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

REFERENCES

Abedin AH, Ahmed MR, Alam MJ (2006). Improvement of input side current of three phase rectifier combining active and passive filters. J. Electric. Eng. IEB, EE 33(I- II):87-90, December 2006.

Ahmed MR (2006). Design of a switch mode ac Voltage regulator with improved power factor. M. Sc. Engineering Thesis, BUET, Department of EEE.

Alomgir H (2005). AC voltage regulation by Ĉuk switch mode power supply. M.Sc. Engineering Thesis, Department of EEE, BUET.

Blasko V, Kaura V (1997). A new mathematical model and control of athree-phase ac–dc voltage source converter. IEEE Trans. Power Electron. 12:116–123.

Busse A, Holtz J (1982). Multiloop control of a unity power factor switching ac to dc converter. Proc. IEEE PESC. 82:171–179.

Habetler TG (1993). A space vector-based rectifier regulator for ac/dc/ac converters. IEEE Trans. Power Electron. 8:30–36.

Kataoka T, Mizumachi K, Miyairi S (1979). A pulse width controlled ac-to-dc converter to improve power factor and waveform of ac line current. IEEE Trans. Ind. Appl. IA-15:670–675.

Kikuch L, Thomas LA (2002). Three-phase PWM Buck-Boost rectifiers with power regenerative capability. IEEE Trans. Ind. Appl. 1(5):

1361-1369.
Ooi BT, Salmon JC, Dixon JW, Kulkarni AB(1985). A 3-phase controlled current PWM converter with leading power factor. Int Conf. Rec. IEEE-IAS Annu. Meet. pp. 1008–1014.
Ruma B (2008). Input Current Improvement of a Three Phase Rectifier by Ĉuk regulator. M.S.c Engg thesis, Department of EEE, BUET, Dhaka, Bangladesh.
Wiechmann EP, Ziogas PD, Stefanovic VR (1984). A novel bilateral power conversion scheme for variable frequency static power supplies. Proc. IEEE PESC 84:388–396.
Wu R, Dewan SB, Slemon GR (1991). Analysis of an ac-to-dc voltage source converter using PWM with phase and amplitude control. IEEE Trans. Ind. Appl. 27:355–364.
Wu R, Dewan SB, Slemon GR(1988). A PWM ac to dc converter with fixed switching frequency, Int. Conf. Rec. IEEE-IAS Annu. Meet. pp. 706–711.
Ziogas PD, Kang YG, Stafanovic VR (1985). PWM control techniques for rectifier filter minimization. IEEE Trans. Ind. Appl. IA-21:1206–1214.