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Comparative Evaluation of AC-DC Converters for Input Current Harmonics : A Study

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Abstract. -In this paper, comparative evaluation of different techniques for harmonic reduction in input current of ac-dc converter is presented. Converters employing ac side switching, resonant converter, active clamped boost converter are simulated in PSIM and their performance under varying load condition with load voltage regulation is evaluated. The results revealed that active clamped boost converter topology has better performance among the cases under study.

Key words

AC-DC converter, Power factor corrections, power quality, current harmonics, current wave-shaping.

1. Introduction

AC-DC converters are used in adjustable speed drives, SMPS, UPS etc. Most of power Electronics (PE) system which get connected to AC utility mains use diode rectifier at the input. The non-linear nature of diode rectifier causes significant line current harmonic generation, thus, they degrade power quality, increases losses, failure of some crucial medical equipment and so on. Therefore, stringent international standard are imposed. Hence, harmonic reduction circuits are incorporated in PE system.

Earlier expensive bulky inductor and capacitor were installed but they effectively eliminated certain harmonic [1]. Active power line conditioners (APLC) used for harmonic reduction are generally hard switched, which result in low efficiency, low EMI, high component stress etc. Soft switched resonant converter are also used and are usually operated in variable frequency mode and thus component are required to be designed at lowest operating frequency [2]. Active clamped technique is well known for zero voltage switching (ZVS) operation in various converters. Boost converter topology in continues conduction mode (CCM) is used in medium power AC-DC converter, as it gives near unity power factor at ac input.

In this paper, three converters techniques- namely AC side switching, Series parallel resonant (LCC) converter and Active clamped boost converter (ACBC) are studied and based on simulation results, their performance for Total Harmonic Distortion (THD) is evaluated. In AC side control technique (fig.1), single switch with L-C pair is used. Duty cycle of the switch is varied like rectified cosine function for the input current wave-shaping. Series parallel resonant converter (SPRC) shown in fig. 2 ; has input diode line rectifier followed by high frequency (HF) inverter, LCC resonant tank circuit, HF transformer and high frequency diode rectifier. To regulate load voltage, switching frequency (above resonance) is varied and ZVS is achieved. In Active clamped boost converter (ACBC) topology shown in fig.3 two switches are driven in complementary manner and average current mode control technique is used for input current wave shaping. These circuits are designed for same power and voltage level and simulated in PSIM software. The simulation results under varying load condition with load voltage regulation are presented. The results show that among the topologies under study, Active clamped boost converter topology has lowest input line current THD.

2. OPERATION OF CONVERTERS

AC Side Control Converter

In this converter single switch is driven by rectangular gate pulse with continuously varying duty cycle. Duty cycle varies from maximum to minimum as the supply voltage sweeps from zero to maximum. Variation in duty cycle is like a rectified cosine function. When switch S is ON provides an alternative path when all the rectifier diodes are reverse biased. The rectifier conducts when switch S is OFF.

Series Parallel Resonant Converter

In SPRC, HF full bridge inverter is operated with gating pulses with duty ratio of 0.5. The switches are operated above resonance to achieve ZVS. To regulate load voltage, switching frequency (f_s) is increased with the decrease in load.

Active Clamped Boost Converter

In ACBC, both the switches are driven in complementary manner. Gating pulses, based on average current mode control, are generated. In average current mode control, boost inductor (L_b) current is continuously monitored and controlled to follow the reference signal proportional to input AC line voltage. Thus, input current is sinusoidal. To maintain constant load voltage, control circuit senses load voltage and automatically reduces the pulse width in switching cycle with decrease in load. Duty cycle is continuously varied over the input supply voltage cycle.

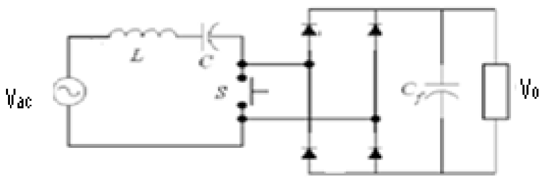


Fig. 1.Single phase rectifier with switching on ac side

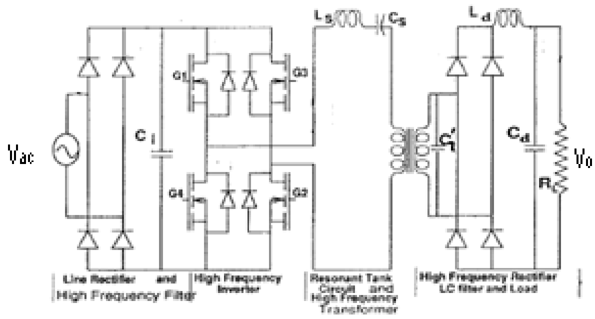


Fig.2 Circuit diagram for ac to dc converter employing SPRC bridge

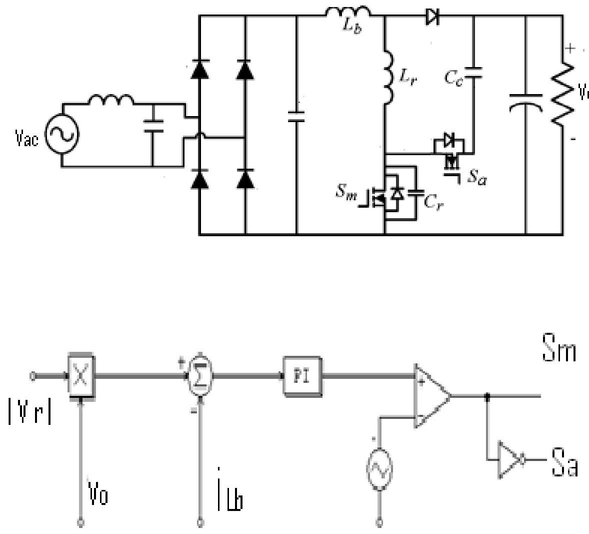


Fig.3 Circuit diagram for single-phase soft switched boost type active clamped ac–dc converter with control scheme

3. DESIGN OF CONVERTERS

All the three converters are designed for the specifications:
Input rms voltage (V_{ac}) = 220V, 50 Hz
Output voltage (V_0) = 370V
Average output power (P_0) = 1.37kW.

The design procedure for AC side control is outlined in [3], for SPRC in [4], and for ACBC topology in [5]. Accordingly the converter components are designed and are as follows:

AC Side Control Converter:

$f_s = 5\ kHZ$, L=100mH, C=101.32μF.

SPRC:

Series resonance frequency (f_{sr}) =43.36 kHz, Switching frequency (f_s) = 50 kHz, L_s =415.226μH, C_s =0.03244μF, C'_t=0.0458μF.

ACBC:

L_b= 850μH, L_r= 8.624μH, C_r=0.47μF, C_c=1.1μF.

4. SIMULATION RESULTS

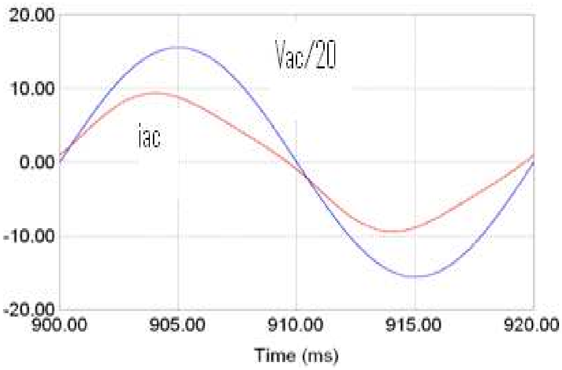
All the three circuit are simulated in PSIM software. Fig.4 shows the simulated input current (i_{ac}), input AC voltage (V_{ac}), harmonic spectra of input current and load voltage (V_o) for AC side control converter and Figures 5 - 6 indicate same for SPRC and ACBC respectively.

Table-I shows variation in % load, % THD, output voltage, switching frequency (f_s) for AC side control converter. From Table-I, it is observed that selection of very high switching frequency does not result in substantial improvement in THD. Table- II shows variation in % load, % THD, output voltage (V_o), switching frequency (f_s) for the different converters under study. From Table-II it is evident that ACBC has minimum THD and good load voltage regulation.

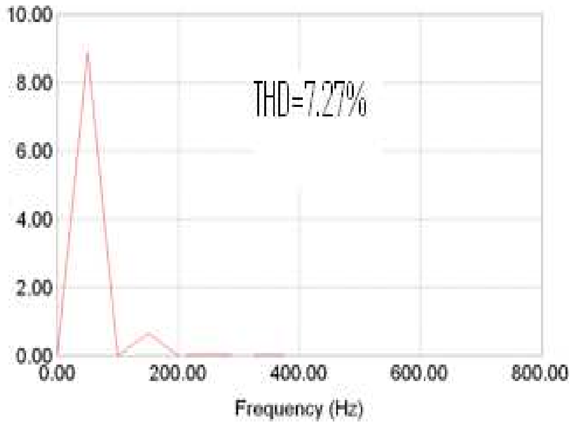
Table I

Variation in % load, % THD, output voltage (*Vo*), switching frequency (f_s) for AC side control converter

f_s in kHz	Full load		50% of full load		25% of full load	
	%THD	V_o in volt	%THD	V_o in volt	%THD	V_o in volt
0.5	8.87	372	17.55	373	35.1	376
1	7.3	372	14.45	372	27.75	372
5	7.27	372	14.25	372	27.44	372
9	7.29	372	14.31	372	27.71	372



(a)



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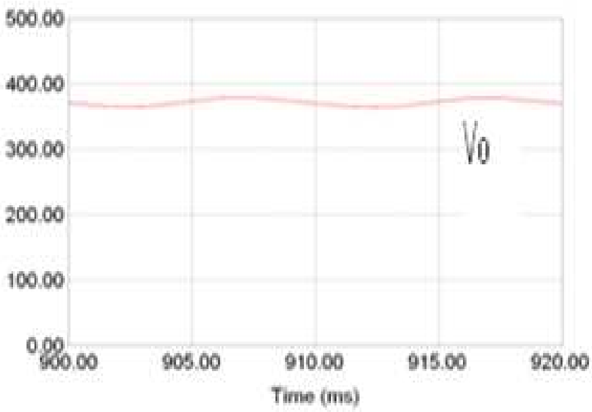
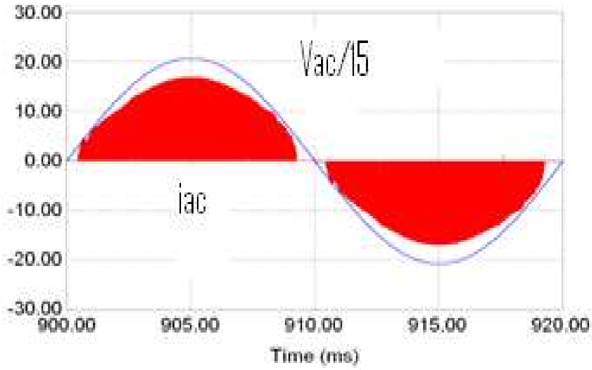


(c)

Fig. 4 Simulated waveforms for AC side control converter at full load
(a) V_{ac} & i_{ac} (b) harmonic spectra of i_{ac} (c) output voltage (V_o)



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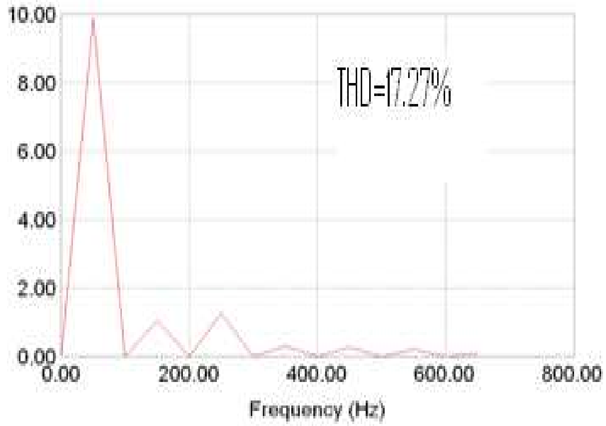

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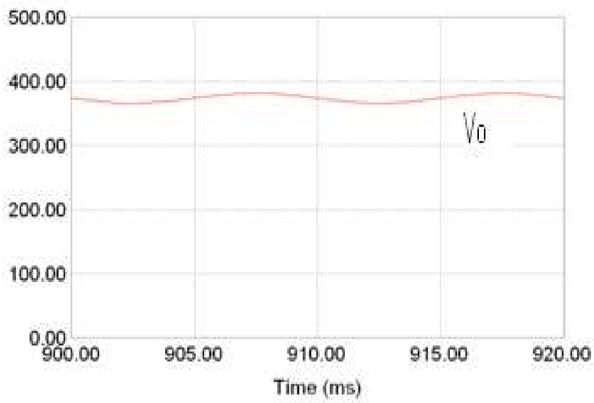
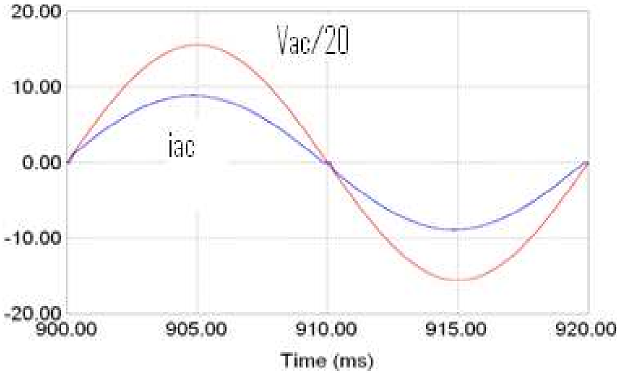


(c)

Fig. 5 Simulated waveforms for SPRC at full load
(a) V_{ac} & i_{ac} (b) harmonic spectra of i_{ac} (c) output voltage(V_o)



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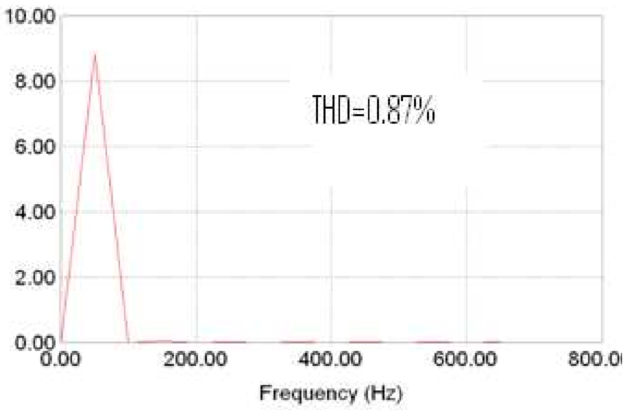

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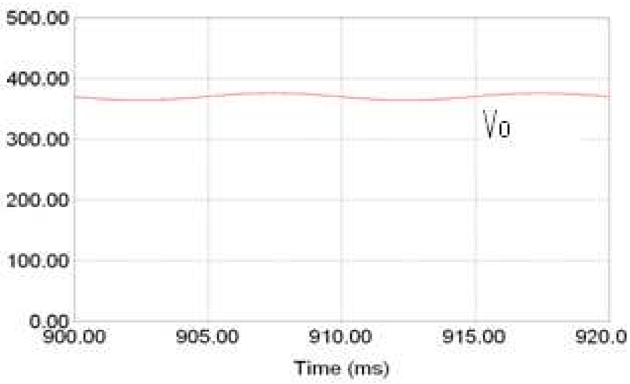

(c)

Fig.6 Simulated waveforms for ACBC at full load
(a) V_{ac} & i_{ac} (b)harmonic spectra of i_{ac} (c) Output voltage (V_o)

5. CONCLUSION

In this paper, AC side controlled converter, SPRC, and ACBC are evaluated for the input current harmonics under varying load condition with load voltage regulation. All the converters are designed for same basic specification. PSIM simulation results are presented. It is observed that for AC side control converter, very high switching frequency does not results in substantial improvement in THD. From the simulation results, it is evident that ACBC has minimum THD and good load voltage regulation.

REFERENCES

[1] B. M. Saied and H. I. Znyal " Minimizing Line Converter Distortion of Three Phase Bridge Rectifier Based on Line Injection Technique" IEEE Trans., power Electronics, Vol.21, pp.1754-1761,Nov 2006.

[2] M. R. Ramteke, H. M. Suryawanshi, K. L. Thakre "Single Phase Resonant Converter in Three Phase System Modular Approach", EPEJ. Vol. 16, No. 4, pp.5-13, Dec. 2006.

[3] Mehjabeen A. Khan, Akeed A. Pavel, M. Rezwan Khan and M. A. Choudhury "Design of a Single Phase Rectifier with Switching on AC Side for High Power Factor and Low Total Harmonic Distortion", Region 5 technical conference 2007, IEEE, pp. 289-292.

[4] Vijaya kumar Belaguli and Ashoka K. S. Bhat, "Operation of the LCC-Type Parallel Resonant Converter as a Low Harmonic Rectifier ", IEEE Trans. on Ind. electronics, vol. 46, no. 2, April 1999,pp. 288-299.

[5] H. M. Suryawanshi, M. R. Ramteke, K. L. Thakre, and V. B. Borghate, "Unity-Power-Factor Operation of Three-Phase AC–DC Soft Switched Converter Based On Boost Active Clamp Topology in Modular Approach" IEEE Trans. on power electronics, vol. 23, no. 1, January 2008, pp. 229-236

[6] Schutten, M. J., Steigarwald, R. L.and Keraluwala, M. H. "Characteristics of Load Resonant Converters in High Power Factor Mode." In *IEEE* Applied Electronics Conference Record, 1991, pp. 5-16

[7] T.-F.Wu and S.-A. Liang, "A Systematic Approach to Developing Single-Stage Soft Switching PWM Converters," *IEEE Trans. Power Electron.*, vol. 16, no. 5, pp. 581–593, Sep. 2001.[5] Z Yang and P C Sen, "Recent Developments in High Power Factor Switch -mode Converters," in IEEE proceedings CCECE 98, 1998, pp.477-480

[8] Oscar Gercia, Jose A. Cobos, Roberto Prieto, Pedro Alou and Javier Uceda, "An alternative to Supply DC Voltages with High Power Factor", IEEE Trans. on Industrial Electronics, vol. 46, no. 4, pp. 703-709, August 1999.

[9] J. He and N. Mohan " Input-Current Shaping in Line-Rectification by Resonant Converters," in *Conf. Rec. IEEE-IAS Annu. Meeting*, 1987, pp. 990–995.

[10] PSIM Software Manual.

TABLE II

Variation of %THD, switching frequency (f_s) and output voltage (V_o) during different load conditions

% of full load	Converter types								
	AC side control converter			SPRC			ACBC		
	% THD	V_o in volt	f_s in kHz	%THD	V_o in volt	f_s in kHz	%THD	V_o in volt	f_s in kHz
115%	6.36	371	5	27.4	350	49	0.74	370	50
100%	7.27	371	5	17.27	373	50	0.87	370	50
66%	10.73	372	5	23.08	368	55.5	1.45	370	50
50%	14.25	372	5	14.74	373	56.8	2.18	370	50
33%	21	372	5	21.35	372	58.2	3.96	370	50
25%	27.44	372	5	29.51	367	59	6.76	370	50