American Journal of Applied Sciences 11 (4): 564-569, 2014
ISSN: 1546-9239

doi:10.3844/ajassp.2014.564.569 Published Online 11 (4) 2014 (http://www.thescipub.com/ajas.toc)

HARMONICS REDUCTION IN FRONT END RECTIFER OF UNINTERRUPTIBLE POWER SUPPLIES WITH ACTIVE CURRENT INJECTION

[1]Chandrasekar, T., [2]B. Justus Rabi and [3]A. Kannan

[1]St. Peter's University, Chennai, Tamilnadu, India
[2]Toc H Institute of Science and Technology, Kerala, India
[3]Dr. M.G.R. Educational and Research Institute, University, Tamil Nadu, India

Received 2013-11-06; Revised 2013-11-12; Accepted 2014-02-01

ABSTRACT

Harmonics are the by-products of modern electronics devices so it is necessary to mitigate the harmonics and offer techniques to mitigation of harmonics. It is greatly hampered by a three phase rectifier used as a front-end ac-to-dc converter in many systems. High power factor is achieved by injecting high-frequency currents into the three-phase rectifier. This study presents the high power factor operation of the converter with reduced total harmonic distortion up to 47.06%. The power quality up gradation is due to high-frequency current injection, at the input of the front-end rectifier. Sinusoidal PWM technique is used for controlling the output voltage. DSP is used for generating the desired gate pulses. The converter has high efficiency, low EMI emissions, high power packing density and suitable for UPS system.

Keywords: High-Frequency-Current-Injection, High-Power-Factor, Soft-Transition, Power-Factor-Correction Circuit

1. INTRODUCTION

Most electronic equipment does not draw their current from the supply as a smooth Sinusoidal waveform. Electronic loads use diodes, Silicon Controlled Rectifier (SCR's), power transistors and other electronic switches to either chop the supplies sinusoidal waveform to control power, or to convert 50 Hz AC to DC. They tend to draw current only at the plus and minus peaks of the line. Since the current waveform is not sinusoidal the current is said to contain "Harmonics". The Uninterruptible Power Supplies (UPSs) have been extensively used for critical loads such as computers used for controlling important processes, some medical equipment. The conventional UPS draws harmonic currents (Shipp and Vilcheck, 1996). Due to its non-linear load, nonsinusoidal current is drawn from the utility and harmonics are injected into the utility lines the Total Harmonic Distortion (THD) factor increases to 70% (Chaudhary and Suryawanshi, 2006). Non Linear Loads are the primary harmonic contributors. The harmonics cause the malfunction of the equipments connected to the Point of Common Coupling (PCC) and also cause excessive heating in the system (Suryawanshi *et al*., 2012). Therefore regulations on line current harmonics have made power factor control, a basic requirement for power electronic equipments (Lai and Key, 2000). Several active power ac to- dc converters are presented in (Prasad *et al*., 1989; Qiu *et al*., 2002; Huang and Lee, 1996). High-frequency current injection methods for power-factor control Resonant converters are presented in (Maswood and Liu, 2006; Hamdad and Bhat, 2004; Belaguli and Bhat, 1999; Cross and Forsyth, 2003). Several soft switching converters are presented in (Bellar *et al*., 1998; Divan, 1986; Vlatkovic *et al*., 1993; Tomasin, 1995; Li *et al*., 2001). In this study, high power factor operation of ac-to-ac converter with Zero Voltage Transition (ZVT) and Zero Current Transition (ZCT) is presented. The ZCT reduces the switching losses in the system. Here its operation is accomplished by taking away the primary device current prior to the switching transitions, by the resonant circuit. The proposed ac-to-ac converter and general block diagramis shown in **Fig. 1 and 2**.

Corresponding Author: Chandrasekar, T., St. Peters University Chennai, Tamilnadu, India

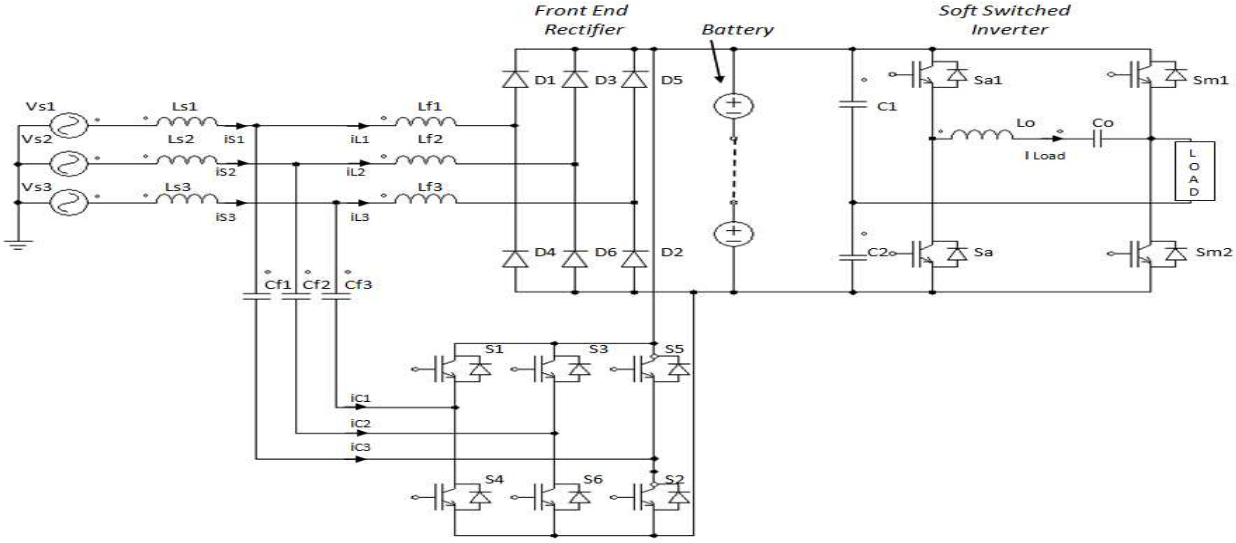

Fig. 1. Ac-ac converter

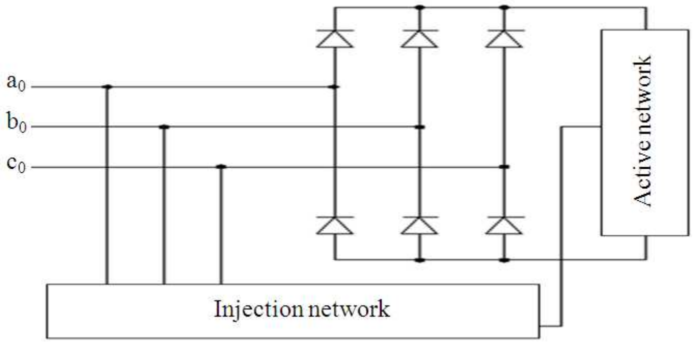

Fig. 2. Block diagram of three phase rectifier with active network

It consists of three-phase input line bridge rectifier (D1-D6) with Power Factor Correction (PFC) circuit, a half-bridge inverter with two primary switches (S_{m1}-S_{m2}) and two secondary switches (S_{a1}-S_{a2}) and L_R-C_R resonant circuit. The PFC consists of three-phase bridge inverter (S_1-S_6) with feed back capacitors (C_{f1}-C_{f3}) and inductors (L_{f1}-L_{f3}). The L_{S1}-L_{S3} is the source inductors. The diodes of the rectifier, primary and secondary switches of half-bridge inverter operate at ZVT and ZCT. The switches of three-phase inverter show ZVT, reducing switching losses considerably. Digital Signal Processor (DSP) TMS320F2812 is used for gating the inverters. The sinusoidal PWM is used for the output voltage control. Computer simulation is carried out for 3 kW, operating at a switching frequency of 50 kHz.

2. PRINCIPLE OF OPERATION

The PFC circuit consists of three phase inverter, capacitors C_f and switched inductors L_f The inverter is switched with high frequency. The High-Frequency (HF) current is injected at the input of three-phase diode bridge rectifier through capacitor C_f causing modulation of input voltage of the diode bridge rectifier. This forces the diodes of the three-phase bridge rectifier to turn-on and turn-off at the switching frequency over the complete cycle of the input supply voltage. In a switching cycle, the input current is the sum of average values of injected current i_{Cf1} and i_{Lf1}. Average value of i_{Cf1} over a switching cycle is zero and peak value of i_{Lf1} follows an envelope of the input supply phase voltage. In each switching cycle this current is reset to zero. Therefore average value of i_{Lf1} also follows the envelope of input voltage. When none of the diodes conducts then supply current flows through C_{f1}. Thus Ls operates in Continuous Conduction Mode (CCM). Therefore the input current is always in phase with the input supply phase voltage, v_{S1}. Hence the converter operates at high-power-factor. For CCM the output voltage of the rectifier should be twice the peak value of input phase voltage (2).

3. ZV AND ZC TRANSITIONS

A zero Current Transition (ZCT) and Zero Voltage Transition (ZVT) are accomplished by a circuit consisting of a half-bridge inverter (S_{m1}-S_{m2}), two secondary switches and a resonant network (L_R-C_R) (Li *et al*., 2001). The basic concept is explained by a simplified circuit shown in **Fig. 3a and b** (Gunwant and Suryawanshi, 2008), the secondary switches, (S_{a1}-S_{a2}) are switched alternately in a definite pattern. To assist the top primary switch S_{m1} for turn-off, an secondary switch S_{a2} is turned on. The L-C resonant circuit starts resonating and resonating current i_R starts to build up and the current in S_{m1} starts to decrease and i_R reaches I_{Load} at t_1. Thus the current in S_{m1} falls to zero and the body diode across S_{m1} starts to conduct surplus current. The gate driver signal can be removed at the zero current condition without causing turn off loss. The same concept is applicable for turn on transition also. As shown in **Fig. 3b**, I_{Load} initially flows through body diode of S_{m2}. During turn on topological stage, the direction of S_{a1} is equivalently changed. Prior to turning on S_{m1}, S_{a1} is turned on for short duration. The current i_R starts to build up in negative direction and reverses its direction at t_1. The current through body diode of S_{m2} decreases due to increasing i_R in positive direction and surplus current passes through body diode of S_{m1} and it can be turned on at t_1. If S_{m1} is gated at this moment then zero voltage switching can be achieved. Moreover i_R flows through body diode of S_{a1}, at this moment the secondary switch S_{a1} can be turned off at zero-current. The same principle is also applicable to turn on and turn off of S_{m2}. Prior to turn on off S_{m2}, secondary switch S_{a2} is gated for short duration. The battery is charged from dc link voltage. Digital sinusoidal PWM technique is used for output voltage wave shaping and magnitude control. A small output filter is used to filter HF content in the output voltage.

4. SIMULATION

In this simulation the prototype is designed with the following parameters:

Input: Three-phase, 400 V, 50 Hz
Output: Single-phase, 220 V, 50 Hz, 3kW
Inverter switching frequency, f_S = 50 kHz, Source Inductors, L_S = 5mH, Feedback inductors Lf =250 μH,
Feedback capacitors, C_f = 2μF,
Split capacitors, C_1 =C_2 = 1000 μF,
Resonant components, L_R = 20 μH, CR = 10 ηF.

5. RESULTS

The computer simulation of proposed converter (**Fig. 4**) is carried out and simulation waveforms are shown in **Fig. 5-9**.

The THD of supply current is found to be 47.06% improved.

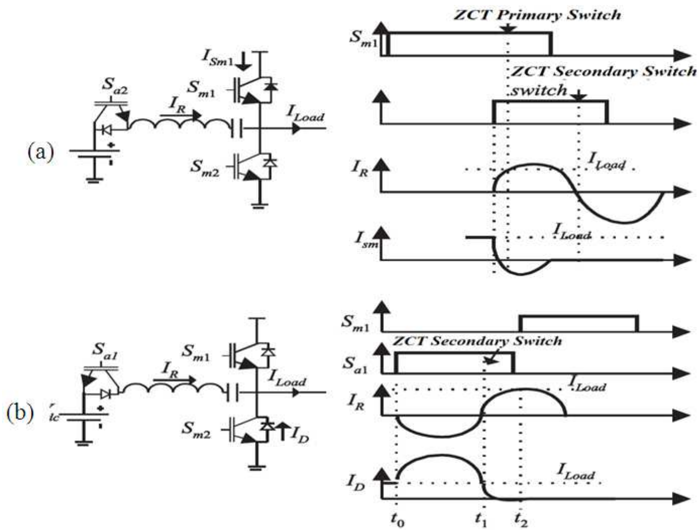

Fig. 3. Transition state of sm1 (a) turn on (b) turn off

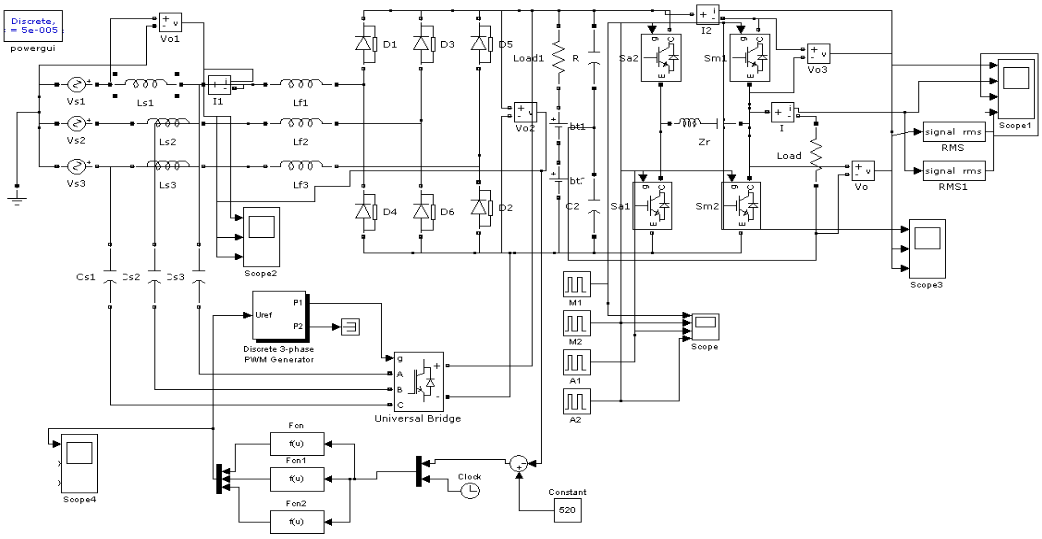

Fig. 4. Front end rectifier with current injection

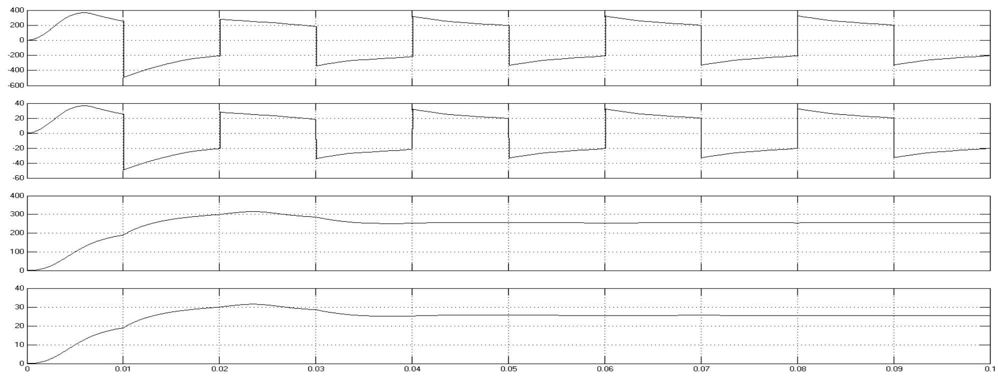

Fig. 5. Simulated wave forms: Current and voltage swith S_{m1}

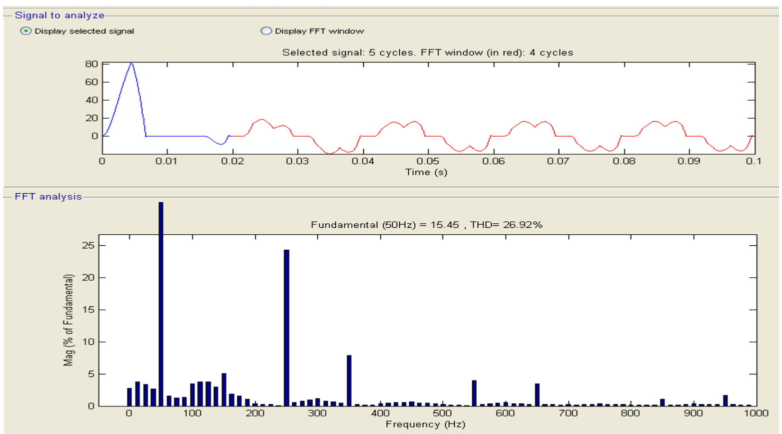

Fig. 6. Before current injection

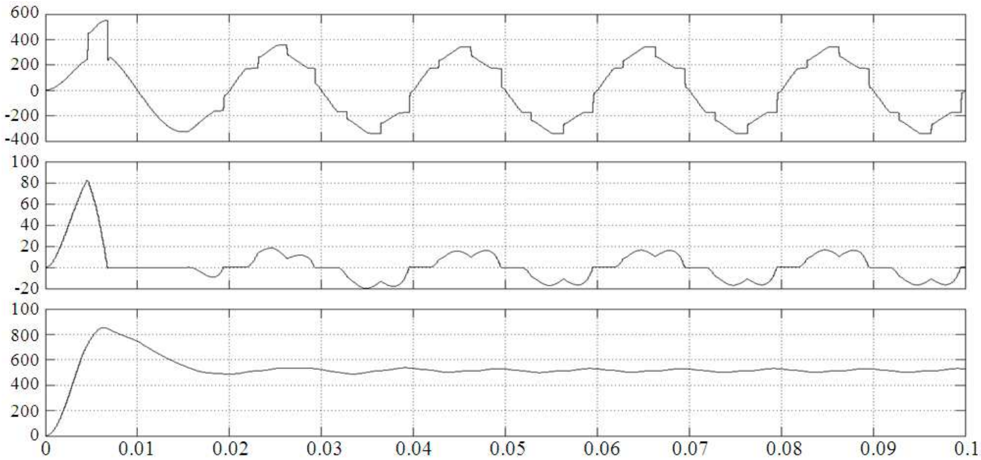

Fig. 7. After current injection

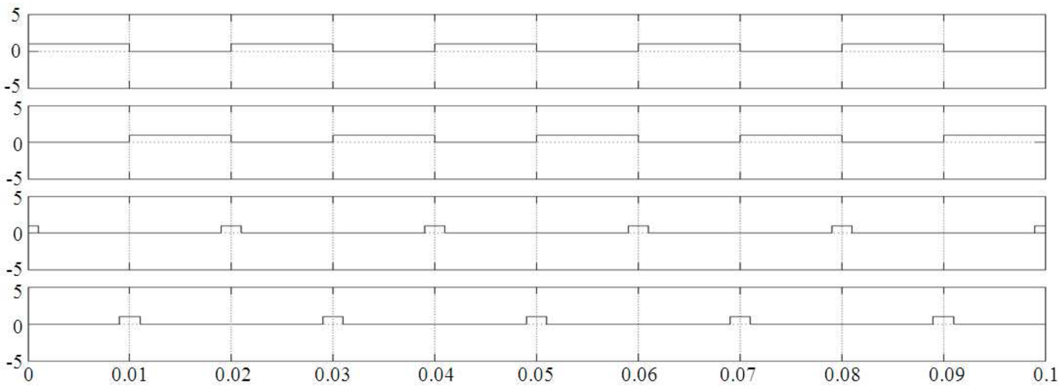

Fig. 8. Pulse pattern for turn on and turn off transitions

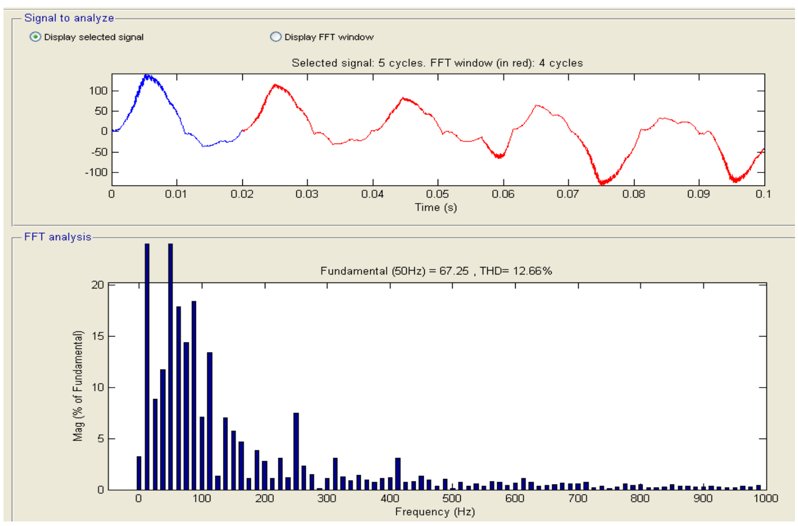

Fig. 9. After current injection

6. CONCLUSION

A harmonics reduction operation in ac-ac converter with soft-switching transition and high power factor is proposed. The soft-switching of primary and secondary switches are achieved thereby greatly reducing the switching losses and EMI emissions. The switches have lower stresses and can be used with high switching frequency. The proposed converter has many advantages such as high packing density, high efficiency and high power factor. Also better output voltage control is obtained.

7. REFERENCES

Belaguli, V. and A.K.S. Bhat, 1999. High power factor operation of DCM series-parallel resonant converter. IEEE Trans. Aerospace Electr. Syst., 35: 602-613. DOI: 10.1109/7.766941

Bellar, M.D., T. Wu, A. Tchamdjou, J. Mahdavi and M. Ehsani, 1998. A review of soft-switched dc-ac converters. IEEE Trans. Indus. Applic., 34: 847-860. DOI: 10.1109/28.703992

Chaudhary, M.A. and H.M. Suryawanshi, 2006. High-power-factor operation of three-phase ac-to-dc resonant converter. IEE Proc. Electric Power Applic., 153: 873-882. DOI: 10.1049/ip-epa:20050510

Cross, M.S. and A.J. Forsyth, 2003. A high-power-factor, three-phase isolated AC-DC converter using high-frequency current injection. IEEE Trans. Power Electron., 18: 1012-1019. DOI: 10.1109/TPEL.2003.813781

Divan, D.M., 1986. The resonant d c-link converter-A new concept in static power conversion. Proceedings of the IEEE-IAS Annual Meeting, (AM' 86), pp: 648-656.

Gunwant, A.D. and H. Suryawanshi, 2008. Power quality enhancement of three-phase front end rectifier of UPS system using current injection technique. Power Q. Utilizat. J., 14: 35-39.

Hamdad, F.S. and A.K.S. Bhat, 2004. Three-phase single-stage AC/DC boost integrated series resonant converter. IEEE Trans. Aerospace Electr. Syst., 40: 1311-1323. DOI: 10.1109/TAES.2004.1386883

Huang, Q. and F.C. Lee, 1996. Harmonic reduction in a single-switch, three-phase boost rectifier with high order harmonic injected PWM. Proceedings of the 27th Annual IEEE Power Electronics Specialists Conference, Jun. 23-27, IEEE Xplore Press, Baveno, pp: 1266-1271. DOI: 10.1109/PESC.1996.548744

Lai, J.S. and T.S. Key, 2000. Harmonic standards: Impact of power electronics equipment design. Power Electr. Technol., 58: 1-13.

Li, Y., F.C. Lee and D. Boroyevich, 2001. A three-phase soft-transition inverter with a novel control strategy for zero-current and near zero-voltage switching. IEEE Trans. Power Electr., 16: 710-723. DOI: 10.1109/63.949504

Maswood, A.I. and F. Liu, 2006. A unity power factor front-end rectifier with hysteresis current control. IEEE Trans. Energy Conver., 21: 69-76. DOI: 10.1109/TEC.2005.853722

Prasad, A.R., P.D. Ziogas and S. Manias, 1989. An active power factor correction technique for three-phase diode rectifiers. Proceedings of the 20th Annual IEEE Power Electronics Specialists Conference, Jun. 26-29, IEEE Xplore Press, Milwaukee, WI., pp: 58-66. DOI: 10.1109/PESC.1989.48473

Qiu, D.Y., S.C. Henry, H.S.H. Chung and H.S.Y. Ron, 2002. Single current sensor control for single-phase active power factor correction. IEEE Trans. Power Electr., 17: 623-631. DOI: 10.1109/TPEL.2002.802173

Shipp, D.D. and W.S. Vilcheck, 1996. Power quality and line considerations for variable speed AC drives. IEEE Trans. Indus. Applic., 32: 403-410. DOI: 10.1109/28.491490

Suryawanshi, H.M., K.L. Thakre, S.G. Tarnekar, D.P. Kothari and A.G. Kothari, 2012. Power factor improvement and closed loop control of an AC-to-DC resonant converter. IEE Proc. Electr. Power Applic., 149: 101-110. DOI: 10.1049/ip-epa:20020288

Tomasin, P., 1995. A novel topology of zero-current switching voltage-source PWM inverter for high-power applications. Proceedings of the 26th Annual IEEE Power Electronics Specialists Conference, Jun. 18-22, IEEE Xplore Press, Atlanta, GA., pp: 1245-1251. DOI: 10.1109/PESC.1995.474973

Vlatkovic, V., D. Borojevic, F.C. Lee, C. Caudros and S. Gatatric, 1993. A new zero-voltage-transition, three-phase PWM rectifier/inverter circuit. Proceedings of the 24th Annual IEEE Power Electronics Specialists Conference, Jun. 20-24, IEEE Xplore Press, Seattle, WA., pp: 868-873. DOI: 10.1109/PESC.1993.472023