International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE) Vol 2, Issue 2, February 2016

Power Factor Correction in Luo Converter Fed Induction Motor Drive

[1] Deepa M.U, [2] Sofiya A [3] Kannan.S.A, [4] Renjith .G [5] Karthyayani P [6] Akhil Krishnan .A
[7] Lekshmi S Kumar [8] Rahul G [9] Sreejith S
[1][2][3][4] Assistant Professors Dept of EEE [5][6][7][8] B.Tech Scholars Dept. of EEE
College Of Engineering Perumon
prasadkarthyayani@yahoo.com

Abstract- **This paper presents a power factor correction (PFC) Luo converter fed induction motor drive. A single voltage sensor is used for the speed control of induction motor and PFC at AC mains. The voltage follower control is used for a Luo converter operating in discontinuous inductor current mode (DICM). The speed of the induction motor is controlled by an approach of variable DC link voltage, which allows a low frequency switching of voltage source inverter (VSI) thus offers reduced switching losses. The proposed induction motor drive of 5 hp is designed to operate over a wide range of speed control with an improved power quality at AC mains. Active power factor correction is done in the proposed system. Simulation of proposed system is done using MATLAB simulink and power quality indices are measured.**

Index Terms: **Bridgeless-LUO converter, induction motor, power factor correction, voltage source inverter.diode bridge rectifier.**

I. INTRODUCTION

Induction machine is the most widely used motor in industry because of its high robustness, reliability, low cost, high efficiency and good self-starting capability [8]. In spite of this popularity, the induction motor has two inherent limitations.They are(i)The standard motor is not a true constant speed machine,its full load slip varies from less than 1%(in hp motors) to more than 5% (in fractional hp motors).(ii)It is not inherently capable of providing variable speed opearation[9]. These limitations can be solved through the use of adjustable speed controllers. The basic action involved in adjustable speed control of induction motor is to apply a variable voltage magnitude variable frequency to the motor so as to obtain variable speed operation [10]. Both the voltage source inverter and current source inverter are used in adjustable speed ac drives [2,3]. In this study, VSI fed three phase induction motor drive system with constant 'dc link voltage control' is simulated using MATLAB. The closed loop speed control of VSI fed induction motor drive system is also described.

Conventional Boost converter is simulated and its total harmonic distortion (THD) and power factor values are recorded. Conventional models uses a front end rectifier which increases the switching losses[4].The THD value was observed to be high(160.09%) and power factor(0.5) was observed to be low.The bridgeless buck and boost converters have been reported in[1] respectively. They suffer from a limited voltage conversion ratio (<1 for buck and >1 for boost converter) which limit its application for a wide range of speed control by varying DC link voltage.

The bridgeless Cuk and SEPIC[3] converters have also gained popularity due to a wide voltage conversion ratio. Power factor correction shapes the input current of off-line power supplies to maximize the real power available from the mains.In order to overcome these drawbacks we go for proposed LUO converter[6].

DICM of LUO converter is used for active power factor correction DCM acts an inherent power factor corrector and hence requires a single voltage control loop(single voltage sensor) for DC link voltage control. A higher stress on PFC converter switch is obtained in PFC converter operating in DICM; hence this mode is preferred for low power applications. Bridgeless converter configurations have gained importance in the past decade due to their high efficiency. The front end diode bridge rectifier is eliminated in these configurations which reduce the conduction losses associated in them. Ideally, the electrical appliance should present a load that emulates a pure resistor, in which case the reactive power drawn by the device is zero. Inherent in this scenario is the freedom from input current harmonics. The current is a perfect replica of the input voltage (usually a sine wave) and is exactly in phase with it. In this case the current drawn from the mains is at a minimum for the real power required to perform the needed work, and this minimizes losses and costs associated not only with the distribution of the power, but also with the generation of the power and the capital equipment involved in the process. The freedom from harmonics also minimizes interference with other devices being powered from the same source.

II. ACTIVE POWER FACTOR CORRECTION

Technically speaking, the term "active power factor correction (pfc)" refers to the method of increasing pf by using active electronic circuits with feedback that control the shape of the drawn current.

There is no direct correlation however, the following equations link total harmonic distortion to power factor.

$$THD(\%) = 100 * \sqrt{\frac{1}{Kd^2} - 1}$$

here Kd is the distortion factor and is equal to

$$: Kd = \frac{1}{\sqrt{1+\frac{THD\ (\%)}{100}^2}}$$

Therefore, when the fundamental component of the input current is in phase with the input voltage, K0 = 1 and:

PF = Kd * K0 = Kd

As illustrated, a perfectly sinusoidal current could have a poor power factor, simply by having its phase not in line with the voltage.

$$PF = \frac{1}{\sqrt{1 + \frac{THD\,(\%)}{100}^2}}$$

III. PROPOSED PFC BASED INDUCTION MOTOR DRIVE

Fig.1 shows the proposed PFC based BL-Luo converter fed Induction motor drive. A single-phase supply followed by filter and a BL-Luo converter is used to feed a VSI driving a Induction motor. The speed of the Induction motor is controlled by adjusting the DC link voltage of VSI using a single voltage sensor. The proposed scheme is designed and its performance is simulated for achieving an improved power quality at AC mains for a wide range of speed control and supply voltage variations. Finally, the simulated performance of the proposed drive is validated with test results on a developed prototype of the drive.

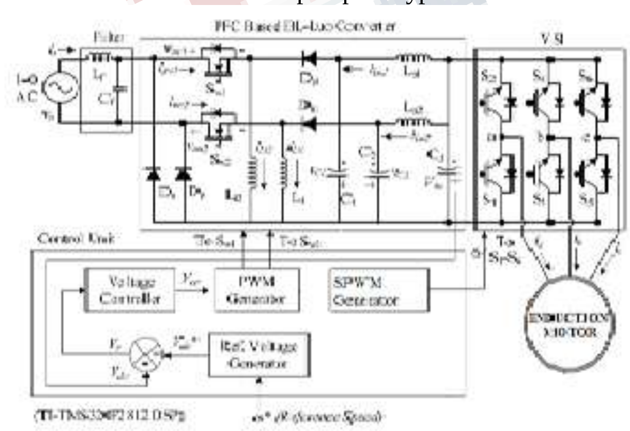

Fig 1: Proposed PFC BL-Luo Converter fed Induction motor drive

IV. OPERATING PRINCIPLE OF PFC BL-LUO CONVERTER

The operation of proposed PFC BL-Luo converter is classified into two parts which include the operation during the positive and negative half cycles of supply voltage (Figs. 2 (a-c) and 2 (d-f)) and during the complete switching cycle.A. Operation during Positive and Negative Half Cycles of Supply Voltage:Figs. 2(a-c) and Figs. 2 (d-f) show the operation of PFC BL-Luo converter for positive and negative half cycles of supply voltage, respectively. The bridgeless converter is designed such that two different switches operate for a positive and negative half cycles of supply voltages. As shown in Fig. 2(a), switch Sw1, inductors Li1 and Lo1 and diodes Dp and Dp1 conduct during the positive half cycle of supply voltage. In a similar manner, switch Sw2, inductors Li2 and Lo2 and diodes Dn and Dn1 conduct during the negative half cycle of supply voltage as shown in Fig. 2(d).B. Operation during Complete Switching Cycle

***Mode P-I*:** As shown in figure switch s1 is turned on. The input inductor Li1 stores energy depending upon the current iL1 and inductance Li1. Energy stored in the intermediate capacitor C1 is transferred to Dc link capacitor Cd and the output side inductor LUO. The voltage across intermediate capacitor (VC1) decreases, whereas the current in output inductor (iLo1) and the DC link voltage (Vdc) are increased

Mode P-II: As shown in Fig. 2(b), when switch Sw1 is turned-off, the input side inductor Li1 transfers its energy to the intermediate capacitor C1 via diode Dp1. Hence, the current iLi1 decreases till it reaches zero, whereas the voltage across intermediate capacitor VC1 increases. The DC link capacitor (Cd) provides the required energy to the load; hence the DC link voltage Vdc reduces in this mode of operation.

Mode P-III: As shown in Fig. 2(c), no energy left in the input inductor Li1 i.e. current iLi1 becomes zero and enters discontinuous conduction mode of operation. The intermediate capacitor C1 and output inductor Lo1 are discharged hence current iLo1 and voltage VC1 are reduced and DC link voltage Vdc increases in this mode of operation. The operation is repeated when switch Sw1 is turned-on again.

In a similar way, for negative half cycle of supply voltage the inductor's Li2 and Lo2, diode Dn1 and intermediate capacitor C2 conduct to achieve a desired operation.

V. DESIGN OF LUO CONVERTER

The current in the input inductors (iLi1 and iLi2) becomes discontinuous in a switching period, whereas the output inductor currents (iLo1 and iLo2) and intermediate capacitor's voltages (VC1 and VC2) remain continuous. A 400W (Pmax) PFC converter is designed to control the DC link voltage . The average voltage (Vin) appearing at the input of filter is given as

$$Vin = \frac{2\sqrt{2}Vs}{\pi} = \frac{2\sqrt{2}*220}{\pi}=198\text{V}$$

The relation between the input and output voltages for a BL-Luo converter is given as

$$d = \frac{V_{dc}}{V_{dc}+V_{in}}$$

Minimum (dmin) and maximum (dmax) duty ratios corresponding to Vdcmin and Vdcmax are calculated as 0.2016 and 0.5025 respectively.The critical value of input inductor operating in DICM for a worst duty ratio of dmin is given as

$$L_{ic} = \frac{d_{\min} \quad (1+d_{min})V_{in}}{2I_0 f_s} = \frac{0.2016(1-0.2016)*198}{2*\left(\frac{100}{50}\right)*20000} = 398\mu H$$

Where fs is the switching frequency which is taken as 20 kHz and Io is the load current.

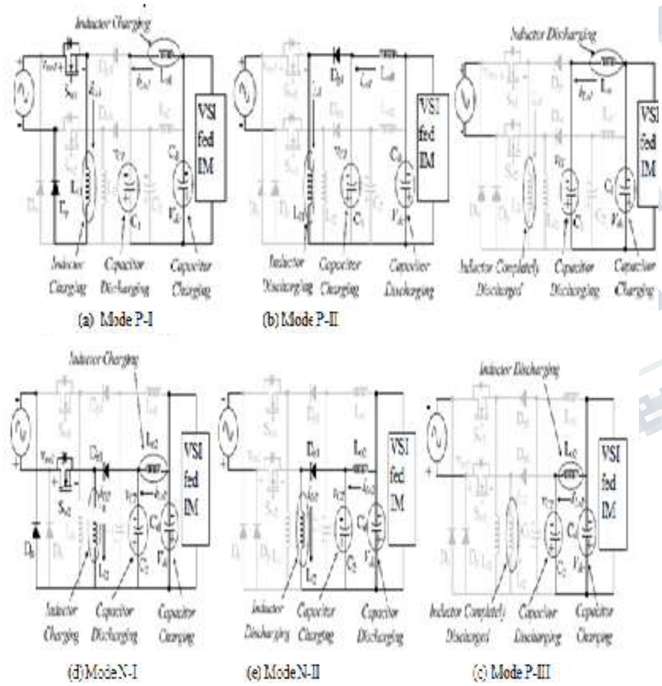

Fig. 2. Different modes of operation of the PFC BL-Luo converter during positive (a-c) and negative (d-f) half cycle of Now, the value of input inductor's is to be selected much less than this critical value to achieve a deep discontinuous conduction over a wide range; hence the selected value of inductors (Li1 and Li2) is taken as 40 uH.

The value of intermediate capacitors (C1 and C2) is calculated for worst duty ratio (dmax) and is given as.

$$C_{1,2} = \frac{d_{max}\, V_c}{2f_s R_L(\frac{\Delta V_c}{2})} = \frac{0.5025*398}{2*20000*100*119.4} = 0.419\mu F$$ Where RL is the emulated load resistance i.e. V_{dc}^2/ Pmax, VC is the voltage appearing across C1 or C2; (i.e. Vin+Vdc) and ΔVC is the permitted voltage ripple which is taken as 60% of VC. Hence the values of intermediate capacitors (C1 and C2) are selected as 0.44μF.

The value of output inductor's (Lo1 and Lo2) for the permitted ripple current in output inductors (which is taken as 10% of Io) is calculated as

$$L_{01,2} = \frac{d_{max}\, I_0}{16{f_s}^2 C_{in}(\frac{\Delta i_0}{2})} = \frac{0.5025*2}{16*20000^2*0.44*10^{-6}*0.2} = 1.78mH$$

Hence value of Lo1 and Lo2 obtained is as 1.78mH.

The value of DC link capacitor (Cd) is obtained for worst duty

ratio $C_d = \frac{I_0}{2\omega_L \Delta V_{dcmin}} = \frac{2}{2*0.314*(0.03*50)} = 2123.14\mu F$

Where ΔVdc is the permitted ripple voltage in DC link capacitor (taken as 3%) and ωL is line frequency in rad/sec. Hence, the DC link capacitor of 2200μF is selected. An input filter (L-C filter) is designed to avoid the reflection of high filter

Current ripple in the supply system. The maximum value of Capacitor (Cmax) is given as

$C_{max} = \frac{I_{peak}}{\omega_L V_{peak}}\tan(\theta) = \frac{\left(400\sqrt{\frac{2}{200}}\right)}{314*220\sqrt{2}}\tan(1) = 459.4nF$ where Vpeak and Ipeak represent peak value of supply voltage and supply current respectively and. Now, the value of filter inductor is designed by considering the source impedance (Ls) of 4-5% of the base impedance. Hence the

additional value of inductance required is given as,

$$L_f = L_{eq} + L_s = \frac{1}{4\pi^2 {f_c}^2 C_f} = L_{req} + 0.04\left(\frac{1}{\omega_L}\right)\left(\frac{{V_s}^2}{P}\right)$$

$$L_{req} = \frac{1}{4\pi^2 2000^2 * 330 * 10^{-9}} - 0.04\left(\frac{1}{314}\right)\left(\frac{220^2}{400}\right) = 3.77mH$$

where fc is the cut-off frequency which is selected such that fL<fc<fS; hence it is taken as fS/10 .Hence, a LC filter of 3.77mH and 330nF is selected.

VI. SIMULATION PARAMETERS

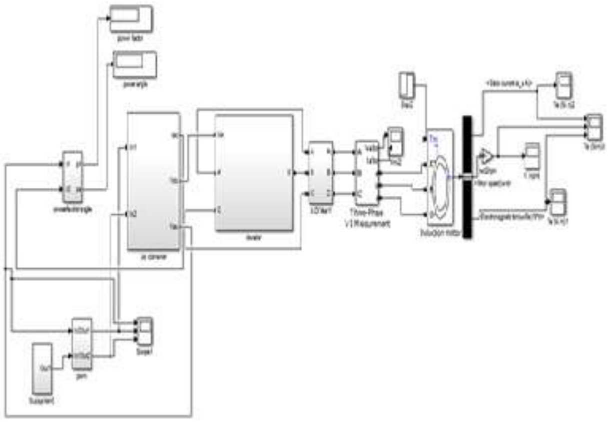

Fig 3 Overall simulation block of proposed IM drive Fig 3 shows the overall simulation block diagram of pfc LUO converter fed Induction motor drive. Using simulink, MATLAB 2014 version the proposed system is simulated. 230V ac supplied to the LUO converter, which acts as a boost converter giving an output of 400v. The output of which is fed to a three phase H-bridge inverter. The ac output passed through a LC filter, is further fed to a 5hp Induction motor. Stator current, Speed and Torque of the induction motor and input current to converter, converter output are observed and measured. A power quality index of the proposed converter is also observe

VII. RESULT ANALYSIS AND COMPARISON

Simulation of conventional boost converter and proposed LUO converter are done in simulink MATLAB 2014 version.Comparitive study of input current,output voltage THD analysis were performed. Induction motor speed, stator current and torque were observed and measured.

Fig 4 shows input current and THD of boost converter.THD of boost converter is 160.09%.This THD level is beyond the permitted level .So we have to go for an improved method.

Fig 4(a) Input current of boost converter

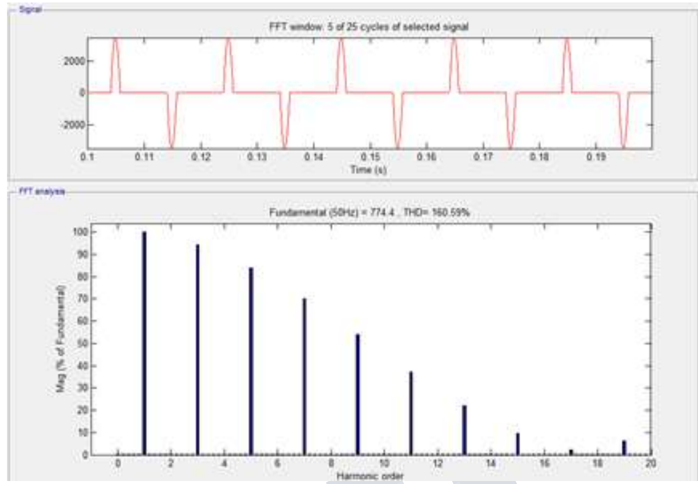

Fig 4(b) THD of Boost converter

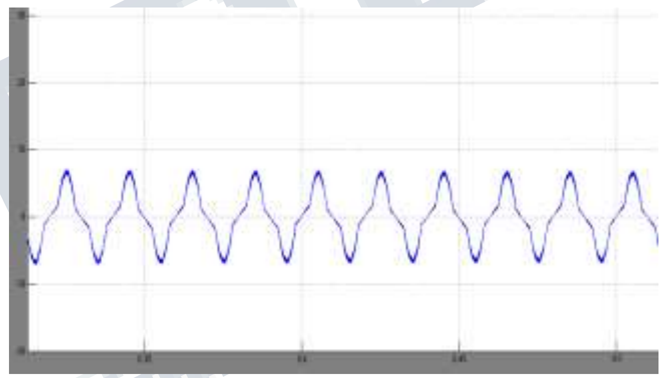

Fig 5(a) Output of boost converter

Fig 5 shows the input current and THD of LUO converter.THD of the LUO converter is 32.62%.

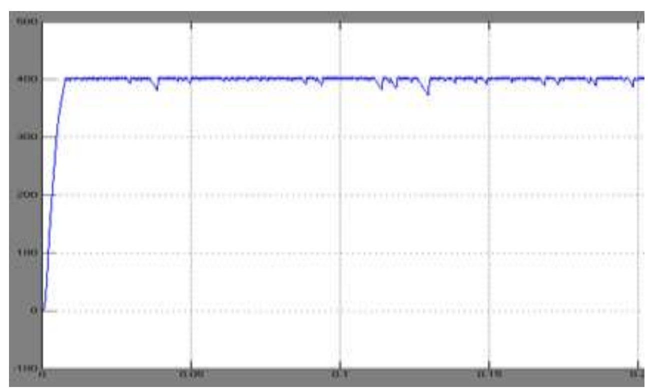

Fig 6(a) output of Boost converter

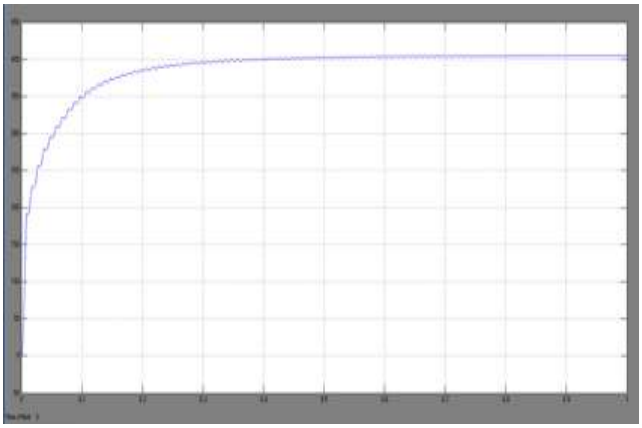

Fig 6(b) Output of LUO converter

Fig 6 shows the output waveforms of boost converter and LUO converter. The converters are designed to get 400V at the output.

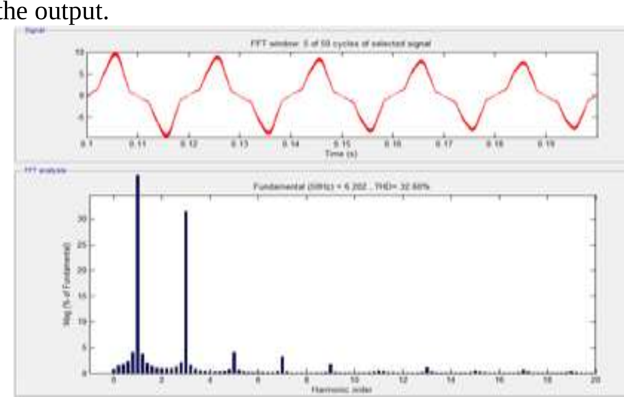

Fig 5(b) THD of LUO converter

TABLE I
COMPARATIVE ANALYSIS OF PROPOSED CONFIGURATION WITH CONVENTIONAL SCHEMES

Schemes → / Attributes ↓	Conventional(boost converter)	Proposed(LUO converter)
THD	160.59%	32.60%
PFC	yes	yes
Power factor	0.5197	0.902

Table I shows the comparison between conventional and proposed system. THD,PFC and power factors were compared. The values of THD and power factor are given.

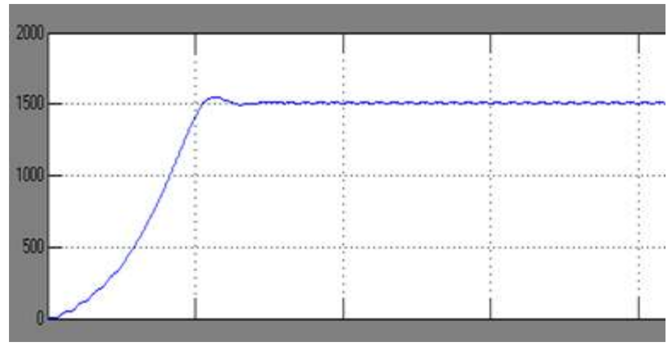

Fig 7(a) Speed Of Induction motor

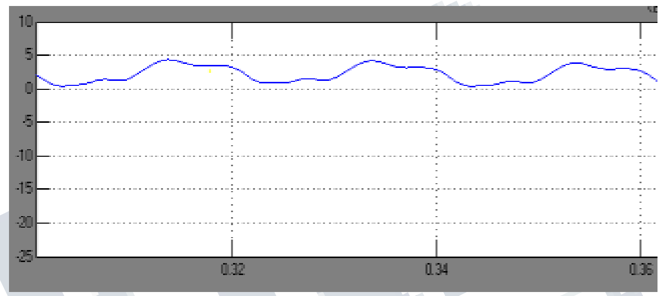

Fig 7(b) Torque of induction motor

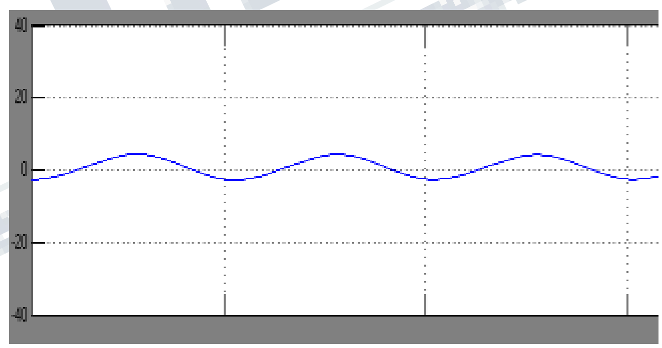

Fig 7(c) Stator current

Fig 7 shows the speed, torque and stator current of induction motor. The speed of induction motor is 1500 rpm. The torque is found to be 4.8Nm.The stator current is 5A.

VIII. CONCLUSION

A PFC based BL-Luo converter fed induction motor drive has been proposed and simulated supply voltages.. The PFC BL-Luo converter has been designed to operate in DICM and to act as an inherent power factor preregulator. An electronic commutation of the BLDC motor has been used which utilizes a low frequency operation of VSI for reduced switching losses. The proposed induction motor drive has been designed and its performance is simulated in MATLAB/Simulink environment for achieving an improved power quality . Finally, the performance of proposed drive has been verified.

REFERENCES

[1]B. Singh, S. Singh, A. Chandra and K. Al-Haddad, "Comprehensive Study of Single-Phase AC-DC Power Factor Corrected Converters With High-Frequency Isolation," IEEE Trans. Ind. Informatics, vol.7, no.4, pp.540-556, Nov. 2011.

[2] N. Mohan, T. M. Undeland and W. P. Robbins, Power Electronics: Converters, Applications and Design, John Wiley and Sons Inc, USA, 2003

[3] D. S. L. Simonetti, J. Sebastian and J. Uceda, "The discontinuous conduction mode Sepic and Cuk power actor preregulators: analysis and design," IEEE Trans. Ind. Electron., vol. 44, no. 5, pp. 630-637, Oct. 1997.

[4] V. Vlatkovic, D. Borojevic and F. C. Lee, "Input filter design for power factor correction circuits," IEEE Trans. Power Electron., vol.11, no.1, pp.199-205, Jan 1996.

[5] F. L. Luo and H. Ye, "Negative output super-lift converters," IEEE Trans. Power Electron., vol.18, no.5, pp. 1113- 1121, Sept. 2003.

[6] F. L. Luo and H. Ye, "Ultra-lift Luo-converter," IEE Proc. Electric Power Appl., vol.152, no.1, pp. 27- 32, 7 Jan. 2005.

[7] I. Yamamoto, K. Matsui and M. Matsuo, "A comparison of various DC-DC converters and their application to power factor correction," Proc. of the PCC (Power Convers. Conf.), Osaka 2002. vol.1, no., pp.128-135 vol.1, 2002

[8] Sangshin Kwak; H. A. Toliyat "A hybrid solution for load-commutated-inverter-fed induction motor drives"
IEEE T oliyat Transactions on Industry Applications

[9] S. Kwak; H. A. Toliyat"A hybrid converter system for high performance large induction motor drives"
Applied Power Electronics Conference and Exposition, 2004. APEC '04. Nineteenth Annual IEEE

[10] Liwei Wang; Carl Ngai-Man Ho; Francisco Canales; Juri Jatskevich High-Frequency Modeling of the Long-Cable-Fed Induction Motor Drive System Using TLM Approach for Predicting Overvoltage Transients IEEE Transactions on Power Electronics
Year: 2010, Volume: 25, Issue: 10

