A Comparative Analysis of Cuk and Buck Boost Converter for PFC in an Induction Motor

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***Abstract**: Power factor correction is essential for ac – dc power supplies because manufactures are forced by the regulatory agencies to minimize harmonic problems. Traditionally we use various methods for power factor correction. This paper deals with a comparative analysis of Cuk and buck boost converter for power factor correction in an Induction motor. Conventional converters uses rectifier circuits with power factor correction but the output voltage is limited. For high controlled voltage range buck boost or Cuk converter should be needed. The performance of the system is evaluated using MATLAB/Simulink environment.*

Keyword: **Power Factor Correction, Cuk Converter, Buck Boost converter, Induction Motor.**

1. INTRODUCTION

Now a days 75% of the electrical machines used in industrial purposes are Three Phase Induction Motors. For earlier industrial applications dc motors were widely used. But many low and medium voltage applications induction motor drives are mainly used because they have rugged construction, robust, cheaper cost and maintenance free due to the absence of commutators, slip rings and brushes. Induction motor can be operated in any environmental condition such as polluted and explosive because they do not have brushes causes sparking problems. These behavior of induction motor make them more prominent in domestic and industrial applications.

Power factor correction (PFC) is needed for ac – dc power supplies in order to minimize the harmonic problems. There are many techniques available for these Power Factor Correction. One of the main technique is adding the passive filter elements like inductor and capacitor to the diode bridge rectifier with input filter. Due to the size of inductors and capacitors having low frequency causes very bulky converters. The other technique is adding an active Power Factor Correction, which has power electronic devices to shape the input line current as sinusoidal with less disturbance to meet the harmonic standard specification. Diode bridge rectifier, buck, boost, buck –boost and cuk converters are used for the implementation of this stage [1].

A bridgeless cuk converter configuration was proposed by V Krishnan et al [2]. In this configuration the input current is highly pulsating which will cause high ripples in output voltage. Wu et al. [3] have implemented a cascaded buck-boost converter, which makes use of two switches for PFC operation. This gives high switching losses within the front end converter due to double switch and reduces the performance of overall system. Ho et. al. [4] have proposed an active power factor correction (APFC) scheme which makes use of a PWM switching of VSI and subsequently has large switching losses. Gopalarathnam et. al. [5] have proposed a single ended primary inductance converter (SEPIC) as a front end converter for PFC with DC link voltage control approach, but utilizes a PWM switching of VSI which has high switching losses. A novel tri-state boost PFC converter operating in Pseudo-Continuous Conduction Mode (PCCM) was proposed by Fei Zhang et al. [6]. The tri-state boost PFC converter provides wider load range and faster dynamic response. An additional power switch is required to make the boost converter operate in PCCM. Bridgeless configurations of PFC buck-boost, Cuk, SEPIC and Zeta converters have been proposed in [7 - 10] respectively. These configurations offer reduced losses in the front end converter but at the cost of high number of passive and active components. Buso et. al.[11] implemented a high-power-factor fly back Cuk and Sepic rectifiers operating in CCM for power factor correction operation. But the topology is complicated causes uneconomic.

2. BLOCK DIAGRAM

Fig. 1, shows the block diagram of the proposed high power factor inverter fed induction motor drive system with PFC. The main components of a power factor corrected induction motor drive system are a rectifier, Cuk converter, three phase Voltage Source Inverter (VSI), induction motor and the control circuit.

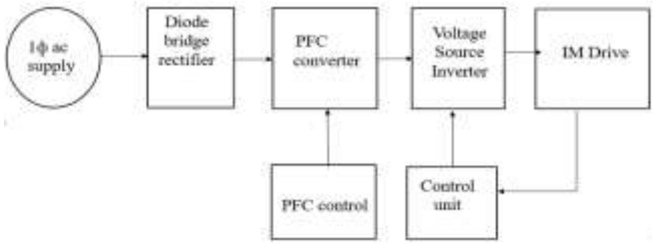

Fig-1 : Block diagram of power factor correction system

The input AC voltage is converted to DC voltage using a bridge rectifier. An LC filter at the output of rectifier helps to reduce the ripple in the output voltage of the rectifier. The output of the bridge rectifier feeds the Cuk converter. The regulated DC link voltage is supplied to a conventional six switch 3 phase VSI which produces an AC voltage that is fed to the induction motor. The power factor correction at the input side of the dc-dc converter is achieved by regulating its output voltage with proper control.

3. OPERATION OF CUK CONVERTER

Cuk converter as shown in fig.2, is a type of DC-DC converter that has an output voltage magnitude either greater than or less than the input voltage magnitude. It uses a capacitor as its main energy-storage component. Cuk converter with proper control regulates the output DC link voltage with power factor correction at the input side.

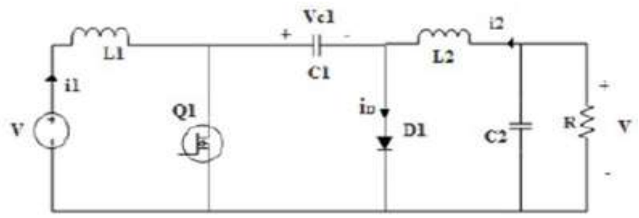

Fig-2: Cuk Converter

Cuk converter operates in both continuous conduction mode (CCM) and discontinuous conduction mode (DCM). In CCM, the current in the inductors (L1 and L2) and the voltage across intermediate capacitor C1 remains continuous in a switching period. In DCM operation, the converter can operate in DICM and Discontinuous Capacitor Voltage Mode (DCVM). In the DICM, the current flowing in inductor L_1 or L_2 becomes discontinuous in their respective modes of operation. While in DCVM operation, the voltage appearing across the intermediate capacitor C1 becomes discontinuous in a switching period.

3.1 CCM Operation

When switch S_w in turned on, inductor Li stores energy while capacitor C_1 discharges and transfers its energy to DC link capacitor C_d. The fig. 3, shows the different intervals in CCM mode.

Input inductor current $i_{L}i$ increases while the voltage across the intermediate capacitor VC1 decreases.

When switch S_w is turned off, then the energy stored in inductor L_o is transferred to DC link capacitor Cd, and inductor L_i transfers its stored energy to the intermediate capacitor C_1. The designed values of L_i, Lo and C_1 are large enough such that a finite amount of energy is always stored in these components in a switching period.

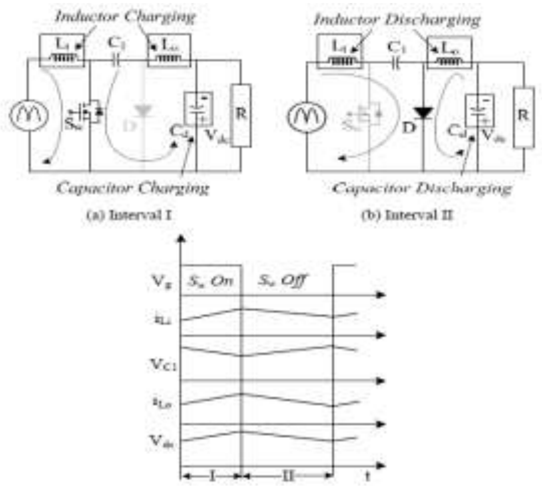

Fig -3: Continuous Conduction Mode

3.2 DCM Operation

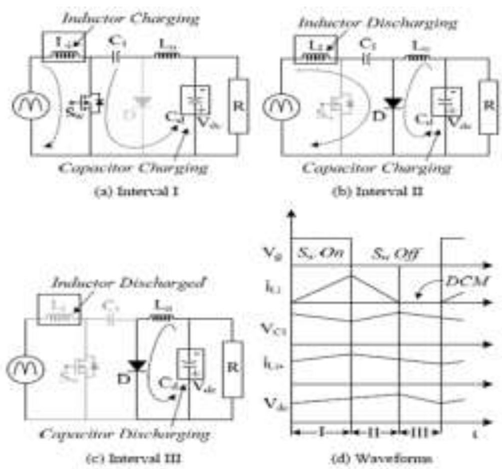

Fig-4: Discontinuous Conduction Mode

When switch S_w in turned on, inductor L_i stores energy while capacitor C_1 discharges through Switch Sw to transfer its energy to the DC link capacitor C_d. Input inductor current i_{Li} increases while the voltage across the capacitor C1 decreases.

When switch S_w is turned off, then the energy stored in inductor L_i is transferred to intermediate capacitor C_1 via diode D, till it is completely discharged to enter DCM operation. During this interval, no energy is left in input inductor L_i, hence current i_{Li} becomes zero. Moreover, inductor L_o operates in continuous conduction to transfer its energy to DC link capacitor C_d. The fig. 4, shows the different intervals in DCM mode.

4. OPERATION OF BUCK BOOST CONVERTER

A buck-boost converter is shown in Fig. 5. The inductor, L is connected in parallel after the switch and before the diode. A capacitor, C is connected in parallel with the load. The polarity of the output voltage is opposite to that of input voltage here.

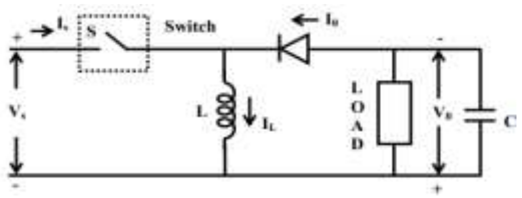

Fig-5: Buck Boost Converter

When the switch, S is put ON, the supply current i_s flows through the path, V_s , S and L, during the time interval, T_{on} . The currents through both source and inductor i_L increase and are same, with $\frac{diL}{dt}$ being positive. The polarity of the induced voltage is same as that of the input voltage. The equation for the circuit is, $V_s = L\frac{diL}{dt}$ Then, the switch, S is put OFF. The inductor current tends to decrease, with the polarity of the induced emf reversing. $\frac{diL}{dt}$ is negative now, the polarity of the output voltage, being opposite to that of the input voltage, . The path of the current is through L, parallel combination of load & C, and diode D, during the time interval, T_{off}. The output voltage remains nearly constant, as the capacitor is connected across the load. The equation for the circuit is, $V_s = L\frac{diL}{dt}$ from which the average value of the output voltage is $V_o = V_s (T_{on} / T_{off}) = V_s\frac{k}{1-k}$ The time period is T = Ton + Toff and the duty ratio is k = (Ton / T). For the range 0 ≥ k ≥ 0.5, the output voltage is lower than the input voltage, thus, making it a buck converter (dc-dc). For the range 0.5 > k ≥ 1.0, the output voltage is higher than the input voltage, thus, making it a boost converter (dc-dc). For k = 0.5, the output voltage is equal to the input voltage. So, this circuit can be termed as a buck-boost converter. Also it may be called as step-up/down chopper.

5. SIMULATION RESULTS

This section deals with simulation results of power factor correction of induction motor drive with and without using Cuk and buck boost converter. The specifications of the induction motor of 0.25HP, 400V, 1425rpm 4 pole, 3phase squirrel cage are specified in Table I.

Table –I: Specification of 3 phase squirrel cage induction motor

Parameters	Value
Stator resistance	11.2 Ω
Stator inductance	0.02 H
Rotor resistance	6.67 Ω
Rotor inductance	0.02 H
Mutual inductance	0.3 H

The designed parameters of Cuk converter and buck boost converter to improve power factor correction are given in table II and table III

Table-II: Designed Values of Cuk Converter

Parameters	Values
Input inductor	0.2×10^{-3} H
Output inductor	20×10^{-3} H
Input capacitor	0.1×10^{-6} F
Output capacitor	10×10^{-6} F
Filter inductor	2×10^{-3} H
Filter capacitor	3.3×10^{-6} F

Table-III: Designed Values of Buck Boost Converter

Parameters	Values
Input inductor	2.2 x 10^{-3} H
Output capacitor	47 x 10^{-6} F
Filter inductor	2 x 10^{-3} H
Filter capacitor	3.3 x 10^{-6} F

The presence of power semiconductor switches in adjustable speed drives results in low power factor and high total harmonic distortion. The rectifier at the front end part is the major reason for low power factor. A voltage source inverter fed 3 phase induction motor using a single phase ac supply with front end rectifier is simulated using MATLAB is shown in Fig 6.

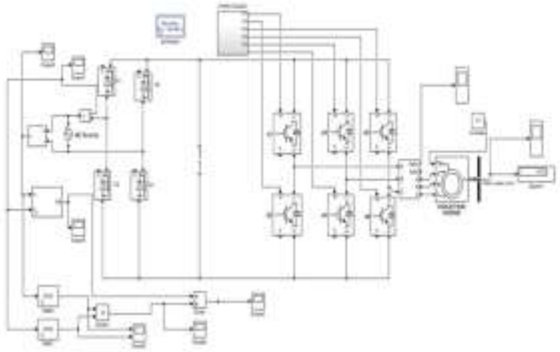

Fig -6: Simulink model of induction motor without PFC

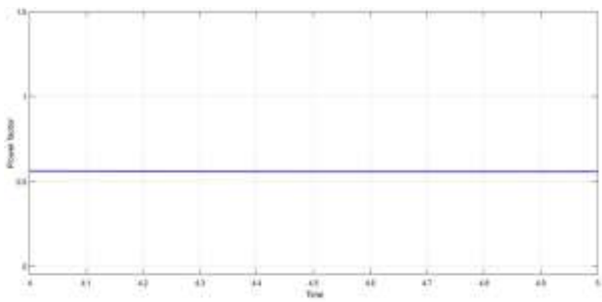

Fig -7: Power factor in 3 phase squirrel cage induction motor without PFC converter

In 3 phase squirrel cage induction motor without using power factor correction converter, the power factor is found to be approximately 0.6 as shown in Fig 7. Power factor correction is achieved using Cuk converter and Buck Boost Converter.

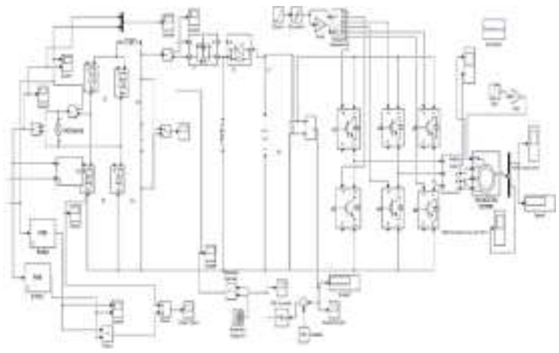

Fig:8- PFC of induction motor using Buck Boost converter

Fig -9: Power factor in 3 phase squirrel cage induction motor with PFC Buck Boost converter

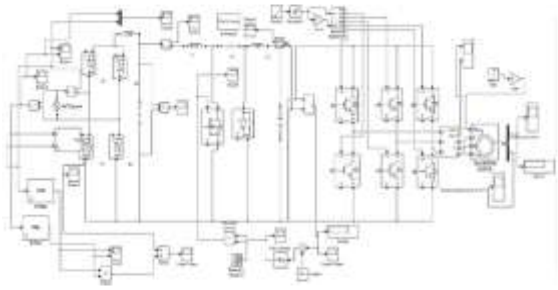

Fig -10: PFC of induction motor using Cuk converter

Fig -11: Power factor in 3 phase squirrel cage Induction motor with PFC Buck Boost converter

Power factor correction is achieved using Cuk converter and Buck Boost converter. The converters are designed to meet the specification of induction motor. Proper control is given to regulate the output voltage of converter and to improve the power factor. The control is obtained using a PI controller. Using the Buck Boost converter the power factor is found to be improved and equal to 0.9 as shown in Fig 9. With the Cuk converter power factor correction is improved and obtained as 0.96 as shown in Fig 11. Comparatively Cuk converter give more power factor correction and low harmonics than Buck Boost converter.

6. CONCLUSION

Inverter fed induction motor without power factor correction is simulated and power factor is observed as low. Using a Cuk converter and buck boost converter power factor correction occurred. Cuk converter and buck boost converter are simulated in MATLAB/Simulink model.

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