# Design & Analysis Of Boost CCM Power Factor Correction Stages Based On Current Rebuilding Concept In Induction Motor

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***Abstract:*** This paper describes the improvement of power factor of an induction motor by using fly back boost CCM power factor corrector. When power factor is improved, automatically energy will be saved A power factor is the goal of any electrical utility company since if the power factor is less than one, they have to supply more current to the user for a given amount of power use. In so doing they occur more line losses. Induction motors are the most widely used electrical motors due to their reliability, low cost and robustness. For industrial and mining applications, 3- phase AC induction motors are the prime movers for the vast majority of machines. It has been estimated that 70% to 80% of all electricity in the world is consumed by these motors. At no load induction motor has very low power factor. It improves at increasing load from no load to full load. Power factor correction is achieved by the addition of fly back boost CCM power factor corrector in parallel with the connected motor circuits and can be applied at the starter, or applied at the switchboard or distribution panel.

## INTRODUCTION:

The main objective of this study is to design an energy saving scheme for an industrial distribution network. This can be achieved by decreasing the network losses and improving the main electric load operation to a better efficiency level. The designed scheme is concerned with improving the power factor of the distribution network by adding shunt capacitors to the network at optimal size and location. Industrial power distribution networks encounters increase in power losses and increase in the type of load is accompanied with low power factor which leads to huge transfer of reactive power from the utility through the network. The main drawback of this problem is increase in the network losses and reduction in the voltage level. It can result in poor reliability, safety problems and higher energy costs. The lower our power factor, the less economically our system operates. The actual amount of power being used or dissipated in a circuit is called true power. Reactive loads such as inductors and capacitors make up what is called reactive power. The linear combination of true power and reactive power is called apparent power. Power system loads consist of resistive, inductive, and capacitive loads. Examples of resistive loads are incandescent lighting and electric heaters. Inductive loads are induction motors, transformers, and reactors and capacitive loads are capacitors, variable or fixed capacitor banks, motor starting capacitors, generators, and synchronous motors.

**PROPOSED POWER QUALITY IMPROVEMENT SCHEME OF IM:**For the proposed voltage controlled drive, a half-bridge DC-DC converter is selected because of its high power handling capacity as compared to the single switch converters. Moreover, it has switching losses comparable to the single switch converters as only one switch is in operation at any instant of time. It can be operated as a single-stage power factor corrected (PFC) converter when connected between the VSI and the DBR fed from single-phase AC mains, besides controlling the voltage at DC link for the desired speed of the Air-Con compressor. A detailed modeling, design and performance evaluation of the proposed drive are presented for an air conditioner compressor driven by a IM motor of 1.5 kW, 1500 rpm rating.

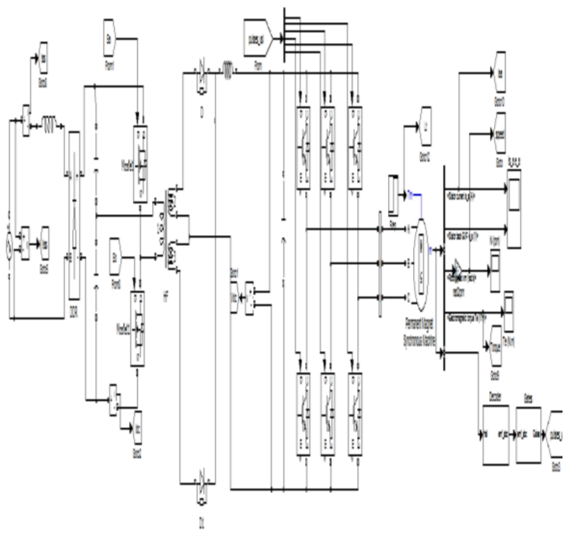

Figure 1. Flyback converter fed IM with current multiplier control

The proposed speed control scheme (as shown in Fig. 1) controls reference voltage at DC link as an equivalent reference speed, thereby replaces the conventional control of the motor speed and a stator current involving various sensors for voltage and current signals. Moreover, the rotor position signals are used to generate the switching sequence for the VSI as an electronic commutator of the IM motor. Therefore, rotor-position information is required only at the commutation points, e.g., every 60°electrical in the three phase. The rotor position of IM is sensed using Hall effect position sensors and used to generate switching sequence for the VSI as shown in Table-I. The DC link voltage is controlled by a half-bridge DC-DC converter based on the duty ratio (D) of the converter. For a fast and effective control with reduced size of magnetic and filters, a high switching frequency is used; however, the switching frequency (fs) is limited by the switching device used, operating power level and switching losses of the device. Metal oxide field effect transistors (MOSFETs) are used as the switching device for high switching frequency in the proposed PFC converter. However, insulated gate bipolar transistors (IGBTs) are used in VSI bridge feeding IM, to reduce the switching stress, as it operates at lower frequency compared to PFC switches. The PFC control scheme uses a current control loop inside the speed control loop with current multiplier approach which operates in continuous conduction mode (CCM) with average current control. The control loop begins with the comparison of sensed DC link voltage with a voltage equivalent to the reference speed. The resultant voltage error is passed through a proportional-integral (PI) controller to give the modulating current signal. This signal is multiplied with a unit template of input AC voltage and compared with DC current sensed after the DBR. The resultant current error is amplified and compared with saw-tooth carrier wave of fixed frequency (fs) in unipolar scheme (as shown in Fig.2) to generate the PWM pulses for the half-bridge converter.

For the current control of the IM during step change of the reference voltage due to the change in the reference speed, a voltage gradient less than 800 V/s is introduced for the change of DC link voltage, which ensures the stator current of the IM within the specified limits (i.e. double the rated current).

**MODELING OF FLYBACK PFC CONVERTER FED IMD**

The proposed PFC buck half-bridge converter is designed for a IM drive with main considerations on PQ constraints at AC mains and allowable ripple in DC link voltage.

The DC link voltage of the PFC converter is given as,

$$V_{dc} = 2\,(N_2/N_1)\,V_{in}\,D \text{ and } N_2 = N_{21} = N_{22} \quad (1)$$

where $N_1$, $N_{21}$, $N_{22}$ are number of turns in primary, secondary upper and lower windings of the high frequency (HF) isolation transformer, respectively.

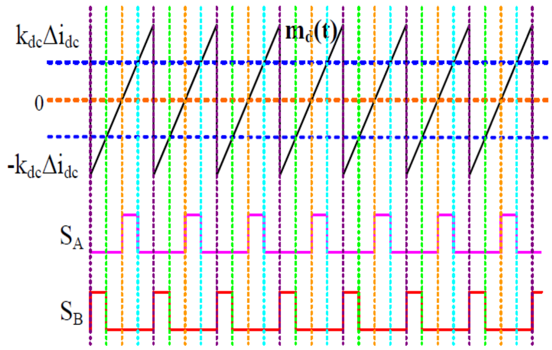


Figure 2. PWM control of the buck half-bridge converter

Vin is the average output of the DBR or a given AC input voltage (Vs) related as,

$V_{in} = 2\sqrt{2}Vs/\pi$ ……………………(2)

The main components of the proposed IM drive are the PFC converter and IM drive, which are modeled by mathematical equations and the complete drive is represented as a combination of these models.

## A. PFC CONVERTER

The modeling of the PFC converter consists of the modeling of a speed controller, a reference current generator and a PWM controller as given below.

***1) Speed Controller***: The speed controller, the prime component of this control scheme, is a proportional-integral (PI) controller which closely tracks the reference speed as an equivalent reference voltage. If at kth instant of time, V*dc(k) is reference DC link voltage, Vdc(k) is sensed DC link voltage then the voltage error Ve(k) is calculated as,

$$V_e(k) = V^*_{dc}(k) - V_{dc}(k) \quad \text{……………..} \quad (3)$$

The PI controller gives desired control signal after processing this voltage error. The output of the controller Ic(k) at $k^{th}$ instant is given as,

$$I_c(k) = I_c(k-1) + K_p\{V_e(k) - V_e(k-1)\} + K_i V_e(k)$$
……………. (4)

Where Kp and Ki are the proportional and integral gains of the PI controller.

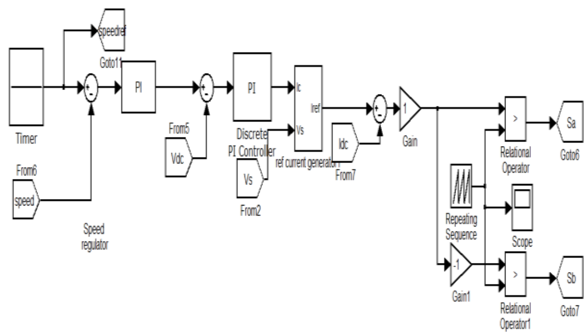


Figure.3 control scheme of proposed motor drive

***2) Reference Current Generator:*** The reference input current of the PFC converter is denoted by idc* and given as,

$$i^*_{dc} = I_c(k)\, u_{Vs} \quad \text{…………….} \quad (5)$$

Where uVs is the unit template of the voltage at input AC mains, calculated as,

$$u_{Vs} = v_d/V_{sm};\ v_d = |v_s|;\ v_s = V_{sm}\sin\omega t \quad \text{…………. (6)}$$

Where Vsm is the amplitude of the voltage and ω is frequency in rad/sec at AC mains.

***3) PWM Controller:*** The reference input current of the buck half-bridge converter (idc*) is compared with its sensed current (idc) to generate the current error Δidc=(idc* - idc). This current error is amplified by gain kdc and compared with fixed frequency (fs) saw-tooth carrier waveform md(t) (as shown in Fig.2) in unipolar switching mode to get the switching signals for the MOSFETs of the PFC buck half-bridge converter as,

If

$$k_{dc}\,\Delta i_{dc} > m_d(t) \quad \text{then } S_A = 1 \text{ else } S_A = 0 \quad \text{……………………………. (7)}$$

If

$$-k_{dc}\,\Delta i_{dc} > m_d(t) \quad \text{then } S_B = 1 \text{ else } S_B = 0 \quad \text{……………………. (8)}$$

Where SA, SB are upper and lower switches of the half-bridge converter as shown in Fig. 1 and their values ‘1’ and ‘0’ represent ‘on’ and ‘off’ position of the respective MOSFET of the PFC converter.

TABLE I. VSI SWITCHING SEQUENCE BASED ON THE HALL EFFECT

SENSOR SIGNALS

| **Ha** | **Hb**<br>**S1** | **Hc**<br>**S2** | **Ea**<br>**S3**<br>**S6** | **Eb**<br>**S4** | **Ec**<br>**S5** |
|---|---|---|---|---|---|
| 0 | 0<br>0 | 0<br>0 | 0<br>0<br>0 | 0<br>0 | 0<br>0 |
| 0 | 0<br>0 | 1<br>0 | 0<br>0<br>0 | -1<br>1 | +1<br>1 |
| 0 | 1<br>0 | 0<br>1 | -1<br>1<br>0 | +1<br>0 | 0<br>0 |
| 0 | 1<br>0 | 1<br>1 | -1<br>0<br>0 | 0<br>0 | +1<br>1 |
| 1 | 0<br>1 | 0<br>0 | +1<br>0<br>1 | 0<br>0 | -1<br>0 |
| 1 | 0<br>1 | 1<br>0 | +1<br>0<br>0 | -1<br>1 | 0<br>0 |
| 1 | 1<br>0 | 0<br>0 | 0<br>1<br>1 | +1<br>0 | -1<br>0 |
| 1<br>0 | 1<br>0 | 1<br>0 | 0<br>0 | 0<br>0 | 0<br>0 |

**B. POWER FACTOR OF AN INDUCTION MOTOR**

The only possible source of excitation in an induction machine is the stator input. The induction motor therefore must operate at a lagging power factor.

This power factor is very low at no load and increases to about 85 to 90 percent at full load, the improvement being caused by the increased real-power requirements with increasing load.

The presence of air-gap between the stator and rotor of an induction motor greatly increases the reluctance of the magnetic circuit.

Consequently, an induction motor draws a large magnetizing current (Im) to produce the required flux in the air-gap.

(i) At no load, an induction motor draws a large magnetizing current and a small active component to meet the no-load losses.

(ii) Therefore, the induction motor takes a high no-load current lagging the applied voltage by a large angle. Hence the power factor of an induction motor on no load is low i.e., about 0.1 lagging.

(ii) When an induction motor is loaded, the active component of current increases while the

magnetizing component remains about the same. Consequently, the power factor of the motor is increased. However, because of the large value of magnetizing current, which is present regardless of load, the power factor of an induction motor even at full load seldom exceeds 0.9 lagging.

Induction machine may become self-excitation when a sufficiently heavy capacitive load is present in their stator circuits.

The capacitive current then furnishes the excitation and may cause serious overvoltage or excessive transient torques.

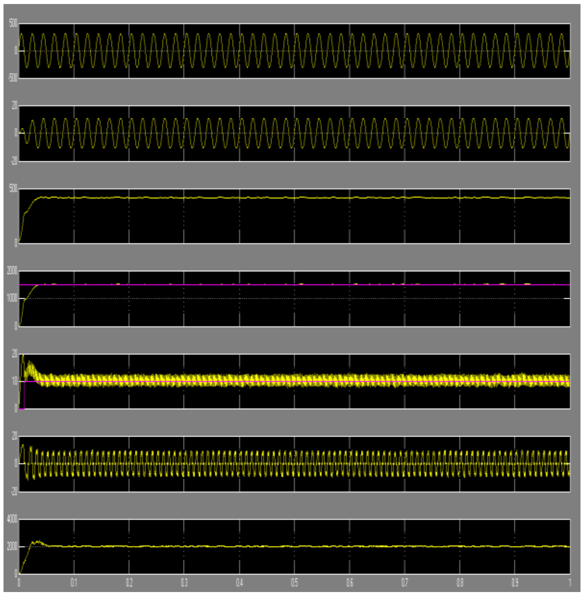

Figure.4 Simulated performance of flyback PFC converter fed IMD during starting at 1000 rpm and speed control (1000 rpm – 1500 rpm – 500 rpm) with current multiplier control

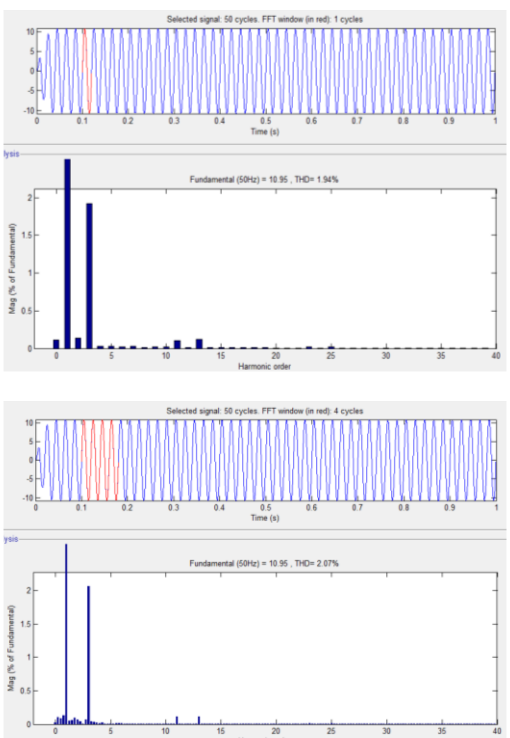


Figure.5 Current waveform at AC mains and its harmonic spectra of the IM drive under steady state condition at rated torque and 220 VAC

## CONCLUSION

A new speed control strategy of a IM drive is validated for a compressor load of an air conditioner which uses the reference speed as an equivalent reference voltage at DC link. The speed control is directly proportional to the voltage control at DC link. The rate limiter introduced in the reference voltage at DC link effectively limits the motor current within the desired value during the transient condition (starting and speed control). The design, modeling and simulation of flyback PFC converter fed IM drive has been carried out in detail for its operation under speed control and varying input ac voltage. After measurements and results obtained measuring the electrical characteristics of induction machine we have come to the following conclusions: A reduction in the overall cost of electricity can be achieved by improving the power factor to a more economic level. The supply will be able to support additional load which may be of benefit for an expanding company. Reducing the load on distribution network components by power factor improvement will result in an extension of their use. It can also be installed in a shorter period of time and is not subject to environmental considerations such as shading or weather.

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