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# Design and Analysis of 4 Kw Srm Drive for Air-Conditioned Pwm Rectifier and Buck-Boost Pfc Converter

**M. Rama Subbamma, V. Madhusudhan,P. Sujatha**

***Abstract: In domestic applications like air conditioners Buck or Cuk converter fed by Permanent Magnet Brushless DC Motors (PMBLDCM) are applicable in literature. Due to drawbacks of economical factor and non availability of permanent magnets these motors are not preferable in these days and are compensated by using Switched Reluctance Motor (SRM) as it has benefits of simple design and low cost. For domestic applications accessible input is AC, a diode bridge rectifier is a simple way of converting AC to DC but it produces lower order harmonics, a low power factor on supply side and variable DC on DC side. In order to overcome this problem PWM rectifier and Buck-Boost Converters are proposed for harmonic mitigation and power factor modification. This paper describes the design analysis (calculations) of 200V, 4KW, 2500 RPM 6/4 pole SRM. Analysis is carried out for SRM drive in air-conditioner (ac) application with PWM rectifier and Buck-Boost converter (BBC) for Power Factor Correction and harmonic mitigation. In proposed work the analysis was carried out for 6/4 SRM with various conditions like initial condition, step variation in dc link voltage, at fixed DC link voltage and variation in source voltage. MATLAB/SIMULINK model of SRM drive for different conditions said above were developed and results were also discussed in this paper. Voltage and current waveforms representing power factor is shown for the SRM drive system with PFC- PWM rectifier and Buck Boost converter. Comparison between proposed converters fed SRM and existing converters like Buck, Cuk converter fed PMBLDCM and Zeta converter fed SRM were given along with their THD. THD was reduced and limited within IEEE standards when operating SRM drive with PFC converter.***

***Keywords: Switched Reluctance Motor (SRM), Buck-Boost converter, Air-Conditioner, Harmonic Mitigation , Power Factor Correction (PFC).***

## I.INTRODUCTION

The nonlinear characteristics of many industrial and commercial loads such as computers, power converters, light regulators and variable speed motor drives (VSDs) used in conjunction with fans, compressors and in air-conditioning equipment have made the harmonic distortion a common occurrence in electrical power systems[1].

Because of the strict requirement of power quality at the input AC mains, various harmonic standards and engineering recommendations such as IEC 1000-3-2, IEEE 519 (USA) [2] are employed to limit the level of distortion at the point of common coupling. Installations utilizing power electronic and nonlinear loads often use one of the growing numbers of harmonic mitigation techniques to follow with these harmonic standards. By using external filtering and by modifications to supply drive system, harmonics can be reduced. The drive construction and load is depended on the current harmonics. These are decreased by the factors including greater DC or AC inductance, higher number of pulses in the rectifier. As an integral part of nonlinear equipment (e.g., an AC line reactor or a line harmonic filter for AC PWM drive) or as a discrete item of mitigation equipment (e.g., an active or passive filter connected to a switchboard), the mitigation may be happened depending on the type of solution desired, There are many ways to reduce harmonics, ranging from variable frequency drive designs to the addition of auxiliary equipment. Few of the most prevailing methods used today to reduce harmonics are line reactors, multi pulse converters, active and passive harmonic filters.

The main contributors of power pollution by poor power quality are the large semi-conductor devices utilized for power processing. Most of power electronic systems draw their input voltage from a stable line voltage source. The improvement in PF, i.e., Power Factor Correction (PFC), also implies harmonic reduction. Generally, the solution for PFC is classified into passive approach and active approach. The advantages of passive approach are ease to maintain, high power handling capability, high reliable and is the best choice for high power applications. Because of the uncertainty of the system impedance and harmonic sources the design is difficult and does not achieve high PF.

To achieve IEEE Std. 519, high-frequency switching techniques have been used to shape the input current waveform successfully. An active PFC approach is employed to accomplish high Power factor, as it dominates the low to medium power applications due to their performance, high density and regulation capabilities. Among the four active PFC techniques (like buck, boost, buck -boost, cuk converters)[3,5,6], buck–boost converter is proposed in this paper for PFC as it has the advantages combined of the buck corrector and the boost corrector to reach the power factor near to unity and less THD. In air-conditioners, Brushless DC motors (BLDC) are used [9,12], other than it has disadvantages of high cost and less life span

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of permanent magnets. In this paper Switched Reluctance (SR) Motor is proposed in position of BLDC motor. Switched Reluctance Motor has an uncomplicated and vigorous fabrication; these terminate indefinite brushes, magnets, commutators and windings on the rotor side. As a result of its fundamental coherence, SR Motor provides benefits of simple design and low cost. For switching the phases, this SR motor drive needs power converters [4]. Asymmetrical bridge converter is proposed for SRM drive to excite the stator windings and it requires a stable DC supply as an input source. It is required to convert AC to DC, because, for domestic applications the accessible input is AC. Use of a diode bridge rectifier is a simple way of converting ac to DC but it produces lower order harmonics, a low power factor on supply side and variable DC on DC side. In order to overcome this problem PWM rectifier and Buck-Boost Converters are proposed for harmonic mitigation and power factor modification.

## II.DESIGN OF SRM FOR 6/4 POLE 4 kW, 2500 rpm SRM

In the design process of SRM, the voltage and current values is to be fixed. For 6/4 SRM the initial design process is done based on the speed, stack length and the number of poles of stator and rotor .The design procedure for calculating inner diameter, outer diameter, stator pole arc, stator yoke width can be calculated. Initially the bore diameter is assumed to be equal to the frame size and the stack length can be equal to the distance between the mounting holes in a foot mounted machine. With the choice of prefatory values of Do, L, D, ßs and ß, the object activity is pursued. Machine torque is to be developed automatically by the speed the output power as

$$T_{req} = \frac{P}{2\pi\left(\frac{N}{60}\right)} Nm$$

$$T_{req} = \frac{4*10^3}{2\pi\left(\frac{2500}{60}\right)} = 15.28 \text{ Nm}$$

$$T_{req} = 15.28 \text{ Nm}$$

For the design process the following considerations were taken:

Electrical loading, $A_S$ = 35000 AT/meter;

Magnetic loading ($B_S$) = 1.62 Weber/mt$^2$

Speed ($N_r$) = 2500 rpm;

Stack length (L) = 114 mm

The equation of the output power of a rotary SRM is given by

$$P = K D_{in}^2 A_s B_s L N_r$$

Where, $K = K_1 K_2 K_e K_d$

Here, $K_1 = 1 - \frac{1}{\sigma_s \sigma_u} = 1 - \frac{1}{10}$

= 9/10 since the salience ratio ($\sigma_s \sigma_u$) lies between 0 and 10.

$$K_2 = \pi^2/_{120} = 0.082246703$$

Efficiency, $K_e$ = 0.85

Duty cycle, $K_d = 1$

Therefore, $K = K_1 K_2 K_e K_d$

K = 0.9 * 0.082246703 * 0.85 * 1

K = 0.062918728.

For power rating of 4 kW (V = 200V, Amps = 20A) with 2500 rpm speed,

Bore diameter can be written as,

$$D_{in} = \left[\frac{4000}{0.062918728*35000*1.62*114*2500*10^{-3}}\right]^{1/2}$$

$D_{in} = 62.72$ mm.

Let the ratio, $\frac{D_O}{D_{in}} = 2$ ;

$D_O = 2 * D_{in}$;  $D_O = 125.44$ mm

### *2.1 Design of stator*

Stator pole arc,

$$\beta_s = \frac{2\pi}{P_S P_R/2}$$

$$\beta_s = \frac{2\pi}{6*4/2} = 30^0$$

Stator pole width,

$$S_{PW} = \frac{D_{in}}{2} \beta_S \frac{\pi}{180} = 16.42 \text{ mm}$$

Stator pole area,

$$A_{SP} = \frac{D_{in}}{2} \beta_S \frac{\pi}{180} * L = 1871.88 \text{ sq.mm}$$

$$\Phi = A_s B_s = 1871.88*114 = 3.03 \text{ m web}$$

The flux in the yoke is given by

$$\varphi_{y=} \frac{\varphi}{2} = \frac{3.03}{2} = 1.5159 \text{ mweb}$$

The area of the yoke Ay can be

$A_y = A_{sp}$ = 1871.88 sq.mm

Stator yoke width,

$$C = \frac{A_{SY}}{L} = \frac{A_{SY}}{L} = \frac{935.94}{114} = 16.4158 \text{ mm}$$

Stator pole height,

$$h_s = \frac{D_O}{2} - \frac{D_{in}}{2} - C$$

$$h_s = \frac{125.4}{2} - \frac{62.72}{2} - 16.4158$$

$$h_s = 14.924 \text{ mm}$$

### 2.2 Design of rotor for 6/4 pole normal SRM

Rotor pole arc,

$\beta_R > \beta_S$

Here $\beta_R = 32^0$

Rotor pole area,

$$A_r = R_{PA} = \left[\frac{D_{in}}{2} - g\right] * \beta_R * \frac{\pi}{180} * L$$

$$A_r = R_{PA} = \left[\frac{62.72}{2} - 0.3\right] * 32 * \frac{\pi}{180} * 114$$

$$A_r = R_{PA} = 1.977 * 10^{-3} \text{ sq m}$$

The flux density of rotor pole Br is

$$B_r = \frac{A_s B_s}{A_r} = \frac{3.03 * 10^{-3}}{1.977 * 10^{-3}} = 1.533 \text{ Tesla}$$

The rotor core area $A_{rc}$,

$$A_{rc} = \frac{A_s}{1.6} = \frac{1871.88}{1.6} = 1.1696 * 10^{-3} \text{ sq.m}$$

Rotor pole height,

$$h_r = \left[\frac{D_{in}}{2} - g\right] - \frac{D_{sh}}{2} - \frac{A_{rc}}{L}$$

$$h_r = \left[\frac{62.72}{2} * 10^{-3} - 0.3 * 10^{-3}\right] - \frac{28}{2} * 10^{-3} - \frac{1.1696*10^{-3}}{114*10^{-3}}$$

$$h_r = 6.8 \text{ mm}$$

### 2.3 Magnetic circuit analysis

Total reluctance of the circuit $= 2R_{SP} + 2R_{RP} + 2R_g + \frac{R_{SY}}{2} + \frac{R_{RY}}{2}$

Magnetic circuit analysis for 6/4 pole machine

$$\text{Area of air gap(Ag)} = \frac{\text{Stator pole width} + \text{Rotor pole width}}{2} * L$$

Area of air gap $= 1.9246 * 10^{-3}$ sq. m

The air gap flux density Bg,

$$B_g = \frac{A_s B_s}{A_g} = \frac{3.03 * 10^{-3}}{1.9246 * 10^{-3}} = 1.57435 \text{ Tesla}$$

The air gap magnetic field intensity Hg,

$$H_g = \frac{B_g}{\mu_0} = \frac{1.57435}{4*3.141*10^{-7}} = 1253064.31 \text{ AT/m}$$

The flux density of rotor core Brc,

$$B_{rc} = \frac{A_s B_s}{A_{rc}} = \frac{3.03*10^{-3}}{1.1696*10^{-3}} = 2.5906 \text{ Tesla}$$

The flux density of stator yoke By is

$$B_y = \frac{A_s B_s}{A_y} = \frac{3.03*10^{-3}}{1.8715*10^{-3}} = 1.6190 \text{ Tesla}$$

### *2.4 Mean Length*

$$l_s = H_s + \frac{C}{2} = 14.924 + \frac{16.4158}{2} = 23.13 \text{ mm}$$

$$l_g = g = 0.3 \text{ mm}$$

$$l_r = \left[\frac{D_{in}}{4} - \frac{g}{2}\right] + \frac{h_r}{2} - \frac{D_{sh}}{2}$$

$$= \left[\frac{62.72}{4} - \frac{0.3}{2}\right] + \frac{6.8}{2} - \frac{28}{2}$$

$$= 4.93 \text{ mm}$$

$$l_{rc} = \pi\left\{\left[\frac{D_{in}}{4} - \frac{g}{2}\right] - \frac{h_r}{2} + \frac{D_{sh}}{4}\right\}$$

$$= 3.141 * \left\{\left[\frac{62.72}{4} - \frac{0.3}{2}\right] - \frac{6.8}{2} + \frac{28}{4}\right\}$$

$$= 60.087 \text{ mm}$$

$$l_y = \pi\left[\frac{D_o}{2} - \frac{C}{2}\right] = \pi\left[\frac{125.4}{2} - \frac{16.4158}{2}\right] = 171.159 \text{ mm}$$

Therefore,

Total reluctance of the circuit$(\Psi) = T_p$

$$= 2(H_s l_s + H_g l_g + H_r l_r) + \frac{H_{rc} l_{rc}}{2} + \frac{H_y l_y}{2}$$

$$H_s = \frac{B_s}{\mu_0 \mu_r} = 28030.4 \text{ AT/m}$$

$$H_r = \frac{B_r}{\mu_0 \mu_r} = 29051 \text{ AT/m}$$

$$H_{rc} = \frac{B_{rc}}{\mu_0 \mu_r} = 1145.51 \text{ AT/m}$$

$$H_y = \frac{B_y}{\mu_0 \mu_r} = 257.72 \text{ AT/m}$$

Total reluctance of the circuit$(\Psi)$

$$= 2(763.26 + 375.91 + 143.22) + 34.4 + 22.02$$

$$= 2631 \text{ Amp-Turns}$$

$$T_{ph} = \frac{\Psi}{i} = \frac{2631}{20} = 132 \text{ Turns}$$

$$i_p = \frac{\Psi}{T_{ph}} = 19.93 \text{ Amp}$$

### *2.5 Parameters of the machine*

Calculation of Inductance (L)

For 6/4 pole machine:

$$L_{alligned} = \frac{T_{ph} * \emptyset}{I_p}$$

We know, Reluctance = $T_{ph} * I_p$

Implies, $T_{ph}$ = Reluctance / $I_p$ ; $T_{ph}$ = 132 turns

Therefore,

$$L_{alligned} = \frac{\Psi * Bs * Asp}{{I_p}^2}, \text{since } \emptyset = Bs * Asp$$

$$L_{alligned} = \frac{2631*1.62*1.8718*10^{-3}}{19.93^2};$$

$$L_{alligned} = 20.07 \text{ mH}$$

The general dimensions, Aligned Inductance of 6/4 SRM for 4kW power rating of SRM are tabulated in Table 1.

**Table-1: General dimensions of SRM**

| S.No. | Parameter | Value |
|---|---|---|
| 1 | Power (P) | 4 kW |
| 2 | Voltage (V) | 200 V |
| 3 | Current ($I_p$) | 20 A |
| 4 | Torque (T) | 15.28 N-m |
| 5 | Electrical loading ($A_s$) | 35000 AT/m |
| 6 | Flux density ($B_s$) | 1.62 Wb/m$^2$ |
| 7 | Speed (N) | 2500 rpm |
| 8 | Stack length (L) | 114 mm |
| 9 | Efficiency ($K_e$) | 0.85 |
| 10 | Duty cycle ($K_d$) | 1 |
| 11 | Inner diameter ($D_{in}$) | 62.72 mm |
| 12 | Outer diameter ($D_0$) | 125.44 mm |
| 13 | Total Reluctance ($\Psi$) | 2631 Amp-Turns |
| 14 | Aligned Inductance ($L_a$) | 20mH |

## III. PWM RECTIFIER FOR SRM DRIVE

In this paper, a non linear control technique for a PWM rectifier associated with IGBT based machine converter is proposed. At the input supply side, a PWM rectifier is connected and is employed as a front end converter for SR Motor drive in order to increase the power factor on ac side. It has furnished Power, Governing unit, PWM Rectifier as AC/DC boost converter, Asymmetrical converter, Capacitor and SR Motor. The foremost characteristics of forepart end converter are less harmonic distortion of the utility current, constrainable power factor & constant DC bus potential.

### 3.1 Proposed System Configuration

SRM with PWM rectifier for power factor correction is shown in Fig. 1. The proposed PWM converter fed SRM drive has an inductor at the input line and a capacitor across front end converter as a DC link. Using power modification strategy, the bridge rectifier controls AC supply to DC. SRM converter fed with DC to SRM drive function. DC link voltage detects and distinguishes with reference DC voltage which gives error signal for power factor correction. Current signal will generate by reducing error signal by means of PI Controller. The actual current signal distinguishes with the obtained reference current value and then resultant signal is again compared to carrier triangular signal thus pulses obtained for the switches. Four switches are required to generate pulses here. The frontend converter consists of four IGBTs governed by power factor correction control methods. The IGBT bridge converter has an amalgamation of a bridge and distinct IGBT keys.

The PWM Gate pulse generator network provides gate pulses and has a combination of current & potential observer. The governor response is stated to discrete PWM producer, which build the controlled pulse as per necessity.

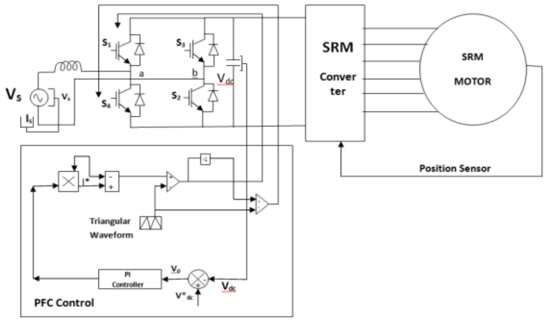


**Fig. 1 Proposed SRM drive for PFC**

### 3.2. Simulation Results and Analysis

The PFC converter for SR Motor drive is modeled and is simulated in MATLAB Simulink environment at various conditions such as Starting condition, Step variation of DC link voltage, constant DC link voltage and variation in ac voltage as explained in following sections 3.2.1 to 3.2.4. Single- phase 320 V, 50Hz ac source is stated to the Pulse Width Modulation rectifier & the DC link potential is regulated to 200V. The IGBT based machine converter is considered for 4kW 6/4 SRM in this simulation. The chief intention of this section is to minimize the input current frequency of oscillations and attain the near to unity power factor on source side. The current waveform of a typical converter is distorted, non-sinusoidal & carrying elevated position of harmonic distortions.

#### 3.2.1 SRM at starting condition.

The simulated output plots of Source voltage, Current, DC link voltage, Speed, Torque and the Armature current of PWM rectifier based SRM at starting condition for 4 kW power rating is as shown in Fig. 2. Fig. 3 shows voltage and current at the supply side. These are in phase and then the power factor is 0.9971 which is near to unity. The THD for source current displays in Fig. 4. It is the inferior point after utilizing Power Factor Correction converter at the forefront.

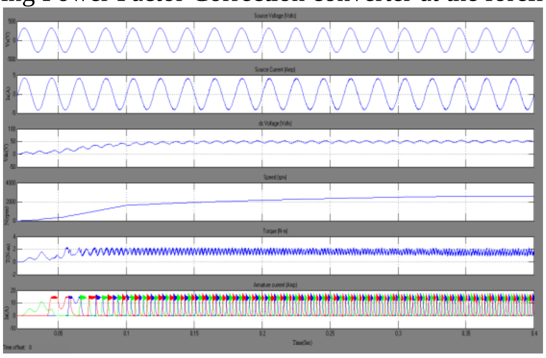

**Fig. 2 Output waveforms of $V_s$, $i_s$, $V_{dc}$, N, T and $i_a$**

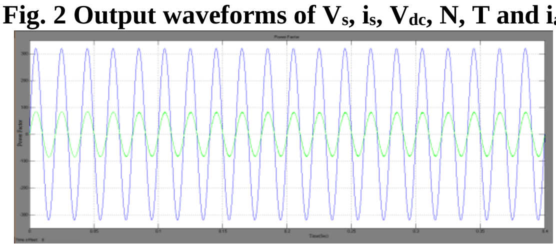

**Fig. 3 Wave form representation of Power factor**

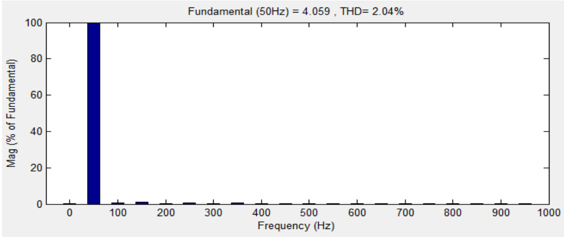


**Fig. 4 Plot of Total Harmonic Distortion (THD)**

#### 3.2.2 SRM with step altering of DC Voltage (from 100V to 150V)

The simulated waveforms of 4kW SRM using PWM PFC rectifier at step modification of DC Voltage from 100V to 150V is shown in Fig. 5. If there is a discrepancy in DC link potential which is increased from 100 to 150V, machine momentum does not alter and is preserved as continual at 2500 rpm by closed loop speed control. Even if the DC link voltage is changing there is no effect on the power factor as shown in Fig. 6 and is maintained close to unity, it is obtained as 0.9966. The total harmonic distortion is 2.88% which is acceptable and is below 5% and is shown in Fig. 7.

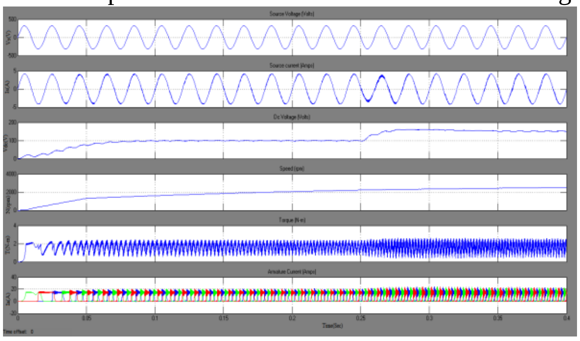

**Fig. 5 Potential, Current at a source side, Rectifier voltage, Momentum, Torque and the Armature Current of SRM**

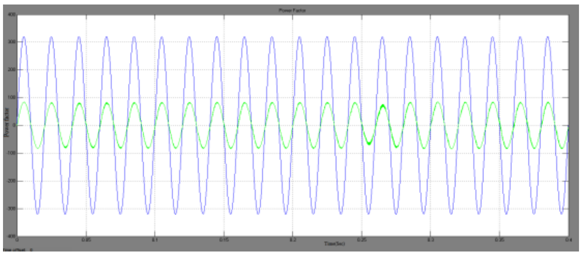

**Fig. 6 Plot of Power factor**

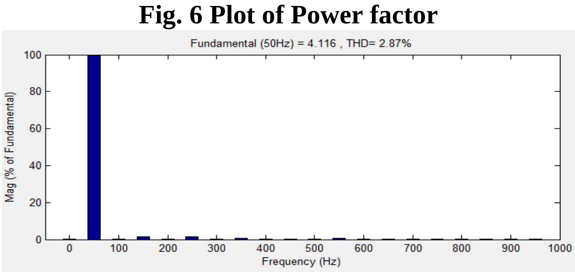


**Fig. 7 THD of a Source Current**

#### 3.2.3 SRM at 200V DC Voltage

The SRM runs at a constant speed of 2500 rpm after t=0.1 sec with constant DC link voltage 200 V as in Fig. 8.

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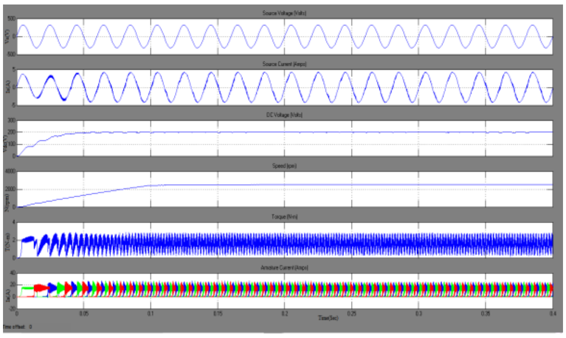

**Fig. 8 Output waveforms of $V_s$, $i_s$, $V_{dc}$, N, T and $i_a$**

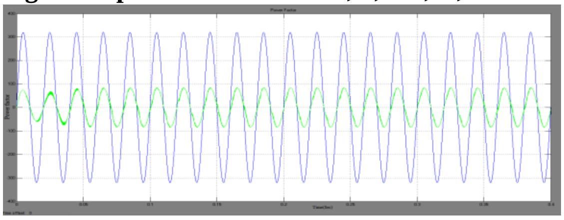

**Fig. 9 Plot of Power Factor**

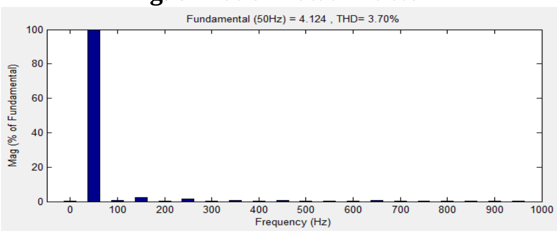


**Fig. 10 Plot of THD**

From Fig. 9, it is shown that the power factor is obtained as 0.9918, which is near unity. Fig. 10 shows THD as 3.70 which is acceptable value.

### 3.2.4 SRM with step alteration of ac Voltage from 320V to 220V

The Simulated results of PFC rectifier fed 4 kW SRM at step modification of Voltage from 320V to 220V is as shown in Fig. 11. Initially, the supply voltage of the model is 320 volts, at t=0.3 sec, the step variation of supply voltage is given to PWM rectifier and the DC link output voltage is fed to SRM converter for its operation. At t=0.3 sec, as the input voltage varies from 320 volts to 220 volts, there will be small variation observed in the current waveform. No variation in the speed even if the input voltage suddenly varies and decreases from 320V to 220V. The speed is maintained as constant with closed loop speed control.

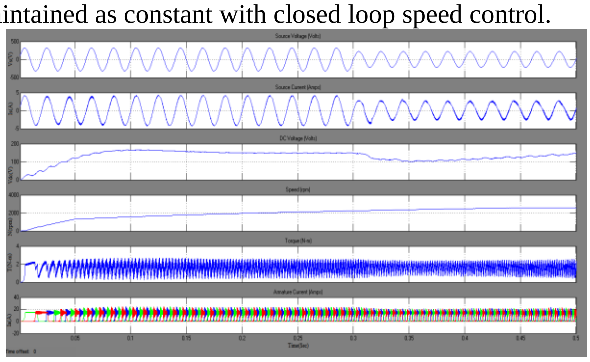

**Fig. 11 Simulated output Wave forms $V_s$, $i_s$, $V_{dc}$, N, T and $i_a$**

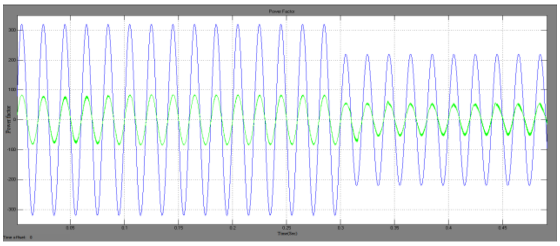

**Fig. 12 Plot of Power Factor**

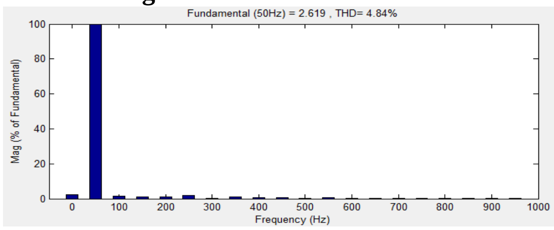


**Fig. 13 THD of Source Current**

Fig. 12 shows the input voltage and current and gives input power factor as 0.9926. Fig. 13 shows that THD profile of input current.

## IV. BUCK-BOOST CONVERTER FOR SRM DRIVE

The buck–boost corrector can provide circuit protections and step-down output voltage as a buck converter and as a boost corrector its input current waveform and output voltage can be tightly controlled. However, the buck–boost corrector has the disadvantage that the polarity of output voltage is reversed and it needs floating drive for the power switch. A linear relationship between current and voltage proves that buck–boost has an excellent automatic PFC property. This is because the input current of buck–boost converter does not related to the discharging period. Furthermore, because the output voltage of buck–boost converter can be either larger or smaller than the input voltage, it demonstrates strong availability for DCM input technique to achieve PFC. So, theoretically buck–boost converter acts as a perfect PFC converter.

### 4.1 Buck-Boost Converter

The Buck-Boost converter fed SR Motor drive for PFC shown in Fig. 14. The frontend converter contains of two MOSFET's controlled by PFC control strategy. Asymmetric converter fed with DC to function SRM drive. DC link voltage is detected and distinguished with reference DC potential which gives error signal for power factor correction. The Current signal will generate by reducing error signal by means of PI Controller. The actual current signal distinguishes with the obtained reference current value and then the resultant signal is again compared to the carrier triangular signal thus pulses obtained for the switches. Two switches are requisite to generate pulses here.

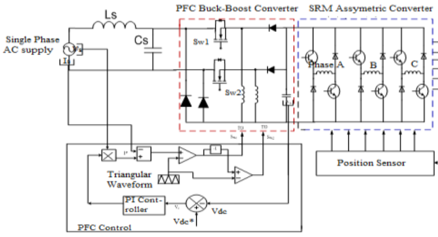


**Fig. 14 Buck-Boost Converter fed SRMD**

### 4.2. Simulation Analysis of 4 kW SRM using Buck-Boost Converter

In this section MATLAB Simulation models and results of PFC based Buck-Boost converter (BBC) fed SR Motor drive at different conditions for 4kW power rating are analyzed at different conditions as explained in the following sections.

#### 4.2.1 Simulation Results at starting condition

The simulation waveforms of supply voltage, supply current, the DC link voltage, Speed (N), Torque and the armature current of proposed 4kW SR Motor are in Fig. 15. Particularly when SR Motor is fed with buck-boost converter, the Source current does not inhere of more ripples as the DC link potential is preserved at constant voltage 50V. SRM attains high starting torque at initial speed. Speed is gradually increase and maintains constant.

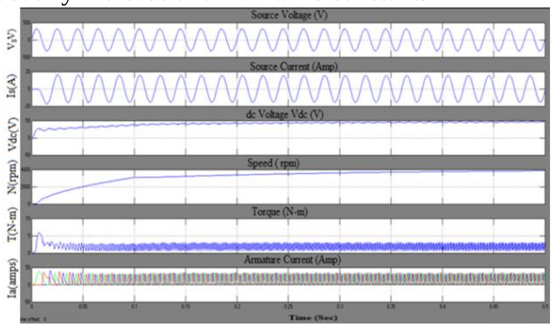


**Fig. 15 Output waveforms of $V_s$, $i_s$, $V_{dc}$, N, T and $i_a$ of SRM**

The SRM will attains high Speed at less time and will exhibits high starting torque at initial condition in the Buck-Boost Converter fed SR Motor drive compared to diode Bridge rectifier fed SRMD as well as PWM rectifier fed SRMD.

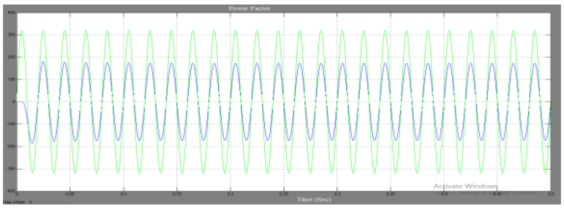


**Fig. 16 Plot of Power Factor**

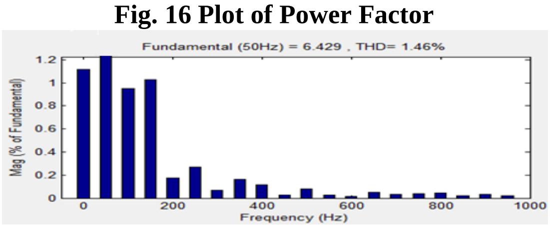


**Fig. 17 THD of Source Current**

Fig. 16 displays the power factor in terms of input voltage and current, are in phase and is 0.995 (almost unity). Fig. 17 shows the total harmonic distortion (THD) profile for input current. It is much lower (0.25%) and acceptable value after using PFC at front end.

#### 4.2.2 BBC fed SRM with Step modification of DC Link Voltage (from 100V to 150V)

Simulated waveforms of $V_s$, $i_s$, $V_{DC}$, speed, torque and the armature currents of SRM with buck-boost converter when the DC voltage is varied from 100V to 150V is in Fig. 18. A Source current does not contain of many ripples when the DC link voltage is adjusted from 100V to 150V. At the time of step modifications, there will be considerable changes in current waveform and then maintained constant after the step variation.

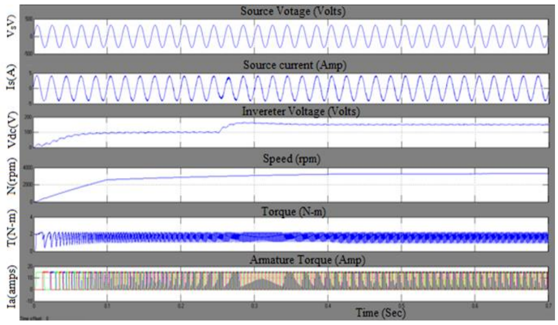


**Fig. 18 Output waveforms of $V_s$, $i_s$, $V_{dc}$, N, T and $i_a$ of SRM**

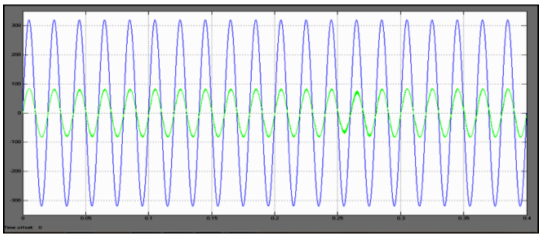

**Fig. 19 Plot of Power Factor**

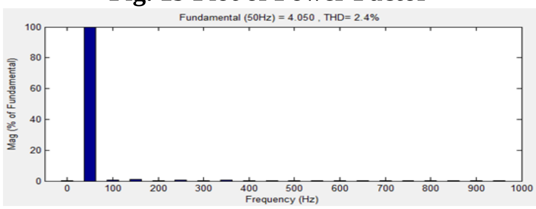


**Fig. 20 THD of Source Current**

If the DC link voltage is altering from 100 to 150V, speed of the machine is maintained as constant. A Plot of the Power factor is as shown in Fig 19 and is 0.9954. A Plot of THD is in Fig.20 and is much lower acceptable value.

#### 4.2.3 BBC based SR Motor with a DC Link potential of 200V

The simulation output waveforms of Source voltage $V_S$, source current $i_s$ and the DC link voltage ($V_{DC}$), speed, torque and armature current of SRM drive with buck-boost converter are in Fig. 21.

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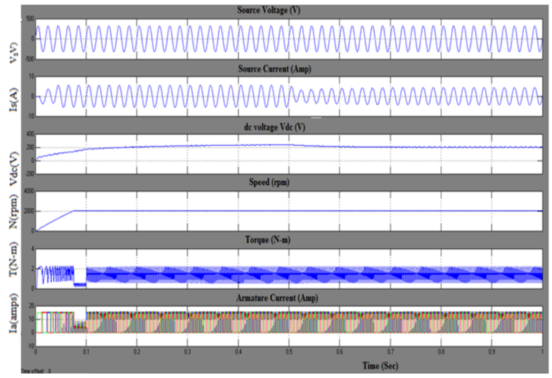


**Fig. 21 Output waveforms of $V_s$, $I_s$ & $V_{DC}$, Speed, Torque and Armature Current**

SRM DC link voltage is set as constant at 200V. Machine speed is maintained as constant if DC link voltage is at 200V constant. Voltage and current at supply mains are in phase and power factor is measured as 0.9966 which is shown in Fig. 22.

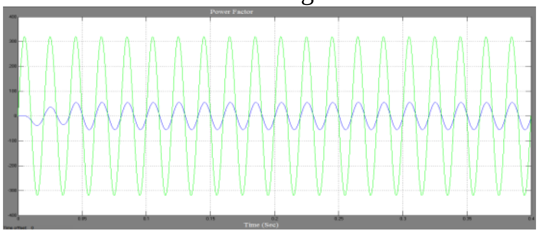

**Fig. 22 Plot of Power Factor**

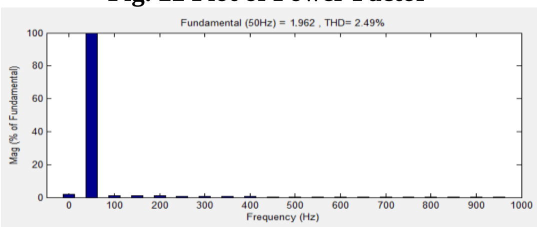


**Fig. 23 Plot of THD**

Plot of THD is shown in Fig. 23 whose value is 2.49% and is acceptable value.

### 4.2.4 PFC Converter for SR Motor with step variation of AC supply Voltage (320V to 120V)

The simulated output waveforms of source voltage, source current and the DC link voltage, N, T, $I_a$ of SRM drive with buck-boost converter when the AC input potential is adjusted from 320V to 120V are shown in Fig. 24.

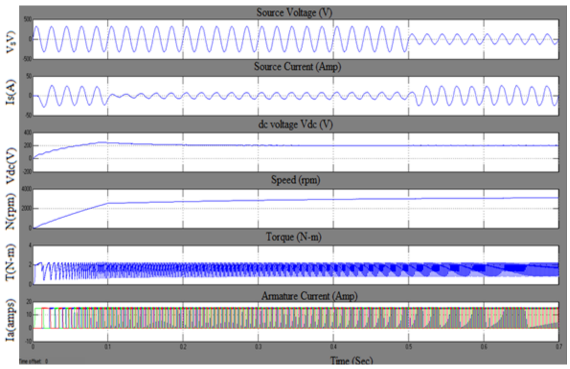


**Fig. 24 Output waveforms of $V_s$, $I_s$, DC voltage, Speed, Torque and Armature Current**

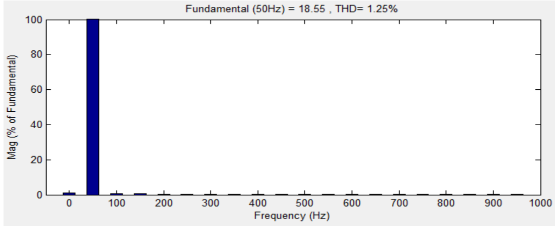


**Fig. 25 Plot of THD**

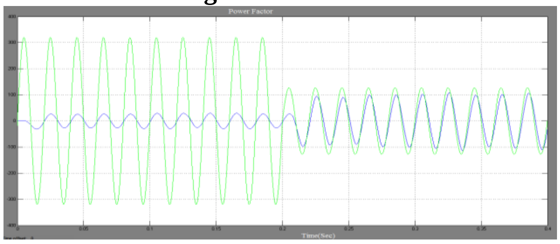

**Fig. 26 Plot of Power Factor**

When the input AC source voltage is reduced from 320 V to 120 V the corresponding source current increases and does not consists of ripples which can be observed from the results. If a source voltage is varying, DC link voltage and machine speed is maintained constant. THD of SRM is shown in Fig. 25 and is acceptable value. The source potential and current of PFC converter is represented in Fig. 26 and is in the same line or in phase. The power factor is 0.9960. For 4 kW power rating of SR Motor Drive, comparisons of THD and power factor between PFC converters are tabulated in Table 2 at various conditions of voltages by maintain speed as constant.

**Table 2 Comparison between PWM PFC and BB PFC for SRMD**

| Rating of SRM | SRM Running Condition | PWM PFC converter | | | | Buck-Boost PFC converter | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $T_{max}$ (N-m) | $T_{min}$ (N-m) | THD (%) | P.F | $T_{max}$ (N- | $T_{min}$ (N-m) | THD (%) | P.F |
| 4kW | Starting | 2.3 | 0.6 | 2.04 | 0.9971 | 2.8 | 0.4 | 1.46 | 0.995 |
| | $V_{DC}$ (100 to 150 V) | 2.4 | 1 | 2.87 | 0.9969 | 2 | 1.4 | 2.4 | 0.9954 |
| | $V_{DC}$=200 volts | 2.6 | 0.2 | 3.70 | 0.9918 | 2.2 | 1.0 | 2.49 | 0.9966 |
| | $V_{ac}$ (320 to 220 V ) | 2.2 | 0.8 | 4.84 | 0.9926 | 2.4 | 0.8 | 1.25 | 0.9960 |

### 4.3 Comparison Between PWM Rectifier And Buck-Boost Converter Fed SRM Drive

This section gives the association between PFC with PWM rectifier and PFC with Buck-Boost converter for SRM drive rated for 4 kW, 150 V (DC) and 1000rpm speed and is compared with zeta converter fed SRM and Buck/Cuk converter fed BLDCM.

### 4.3.1 PFC with PWM rectifier

Fig. 27 shows simulation results of supply voltage, supply current, DC link voltage, speed, torque and the armature current of SRM. DC link voltage at 150V and speed at 1000 rpm were maintained and the distinctiveness was attained at condition. The Power factor of the system with PFC using PWM rectifier is 0.997 maintained near to unity as no phase difference was observed between supply voltage and current as in Fig. 28. Total harmonic distortion in Fig. 29 was 1.10% and maintained below 5% which is acceptable.

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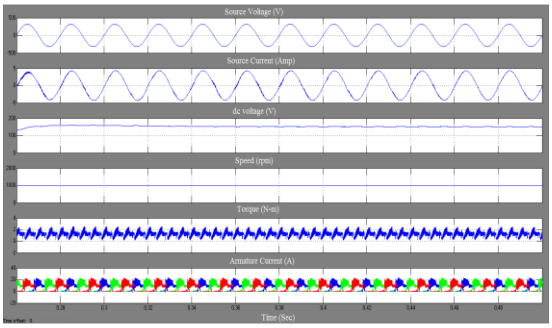

**Fig. 27 Simulation waveforms of $V_s$, $I_s$, $V_{dc}$, N,T and $i_a$ of SRM**

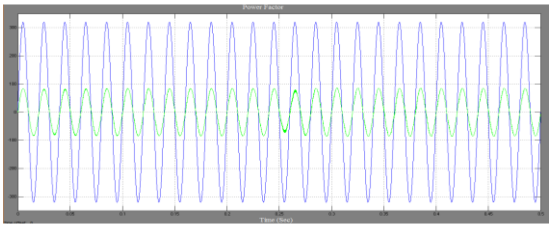

**Fig. 28 Plot of power factor**

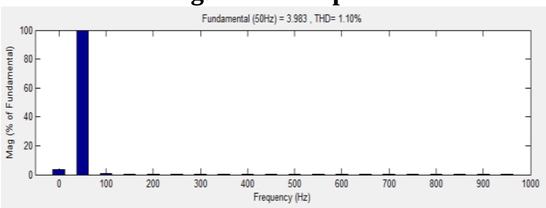


**Fig. 29 Simulation output of total harmonic distortion in Source Current**

### 4.3.2 PFC with Buck-Boost Converter

Employing of PWM rectifier involves more number of switches for power factor correction. So in order to diminish the cost and build up the power factor, buck-boost converter is analyzed in section 4.4.2. In the current control strategy, the actual speed and error signal are fed to PI controller. It produces current reference shape by the rotor is evaluated and it proliferates to current reference magnitude generating reference current signal, which distinguish with actual current and error signal is post to hysteresis current governor fabricates pulses to the switches in SRM converter.

Fig. 30 shows simulation results of supply voltage, supply current, $V_{dc}$, speed, torque and the armature current of SR Motor. At DC link voltage 150V, speed 1000 rpm the Buck-Boost converter for PFC is maintained near to unity as no phase difference has observed between supply voltage and current as displayed in Fig. 31.

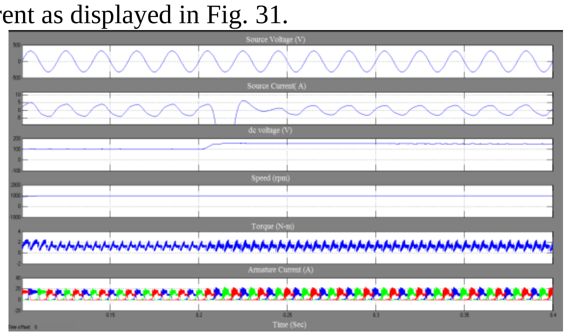

**Fig. 30 Simulation waveforms of $V_s$, $I_s$, $V_{dc}$, N, T and $i_a$ of SRM**

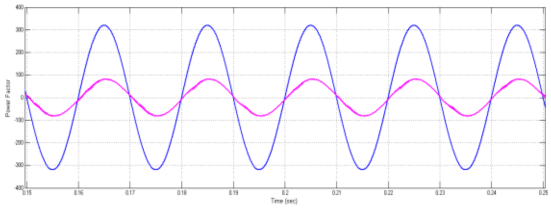

**Fig. 31 Plot of Power Factor**

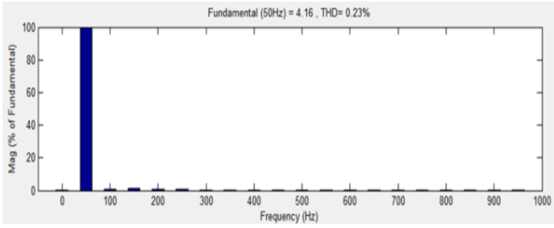


**Fig. 32 Plot of total harmonic distortion in a Source Current**

Total harmonic distortion in Fig. 32 was 0.28% and maintained below 5% which is acceptable and less than obtained in PWM rectifier. Two switches are driven by one driver by using a NOT gate. In Buck-Boost PFC converter only one driver circuit is required to drive two switches. Eventually driver losses will be high in PWM rectifier than compared to Buck-Boost type of PFC converter.

The Comparison of THD between PWM rectifier and Buck-Boost converter fed SRMD are listed in Table 3 for DC link voltage 150 V and speed of 1000rpm. PWM rectified fed SRMD and Buck-Boost converter fed SRMD has less THD compared to isolated zeta converter fed SRMD [5], buck converter fed BLDCMD[12] and Cuk converter fed PMSMD[8] and maintains near to unity power factor in both the converters.

**Table 3 Comparison of THD and power factor for various PFC converter fed motors**

| Type of Motor / Parameter | Buck converter fed BLDCM | Cuk converter fed PMSMD | Isolated Zeta Converer fed SRMD | PWM Rectifier fed SRMD | Buck-Boost Converter fed SRMD |
|---|---|---|---|---|---|
| DC link Voltage (V) | 150V | 400V | 150 | 150 | 150 |
| Speed (rpm) | 1400 | 1000 | 1000 | 1000 | 1000 |
| THD (%) | 1.88 | 5.57 | 7.68 | 1.10 | 0.28 |
| Power Factor | Near to unity | 0.9989 | Near to unity | 0.997 | 0.9966 |

## V.CONCLUSION

The most effective of the switching angles in SRM drive with PWM governors have been organized and analyzed with simulation executions. The switch ON and switch OFF angles are used in PWM and is optimized so as to get considerably a high power factor of SRM drives and to take care of the desired speed. To improve the potential problems of SR Motor, it is accomplished by turn on and turns off angles for the potential applied. The designed scheme is suitable for both the bottom grading and top grading of SRM drives.

The analysis is carried out for 4kW power rating of 6/4 pole SRM drive with both PWM PFC rectifier and Buck-Boost converter at different conditions like SRM at starting, when DC link voltage is kept constant, when DC link voltage is varied (step-change) and also when AC voltage is varied (step-change). Results confirm that the usage of Buck-Boost PFC converter for SRM drive attained high Speed at less time and exhibits high starting torque at initial condition compared to diode Bridge rectifier fed SRMD as well as PWM rectifier fed SRMD. It also improves power factor maintaining the source voltage and current in-phase and making the power factor near to unity. In both the cases, PWM rectifier and Buck-Boost PFC Converter fed SRMD, THD is analyzed and is less when compared to existing methodologies (Buck, Cuk and Isolated zeta converters) for the same rating of machine.

## REFERENCES

1. Reinert J, Schroder S. Power-factor correction for switched reluctance drives. IEEE Transactions on Industrial Electronics. 2002;49(1):54–57. DOI: 10.1109/41.982248.
2. Austin Hughes and Bill Drury "Electric Motor Drives Fundemaentals, Types and Applications" ISBN: 978-0-08-098332-5, Copyright 1990, 1993, 2006, Austin Hughes. Published by Elsevier Ltd, 2013 Fourth Edition.
3. Vikas S. Wadnerkar "Performance Analysis of swiched Reluctance motor" JTAIT, 2005-2008, pp 1118-1124.
4. Samia M. Mohmoud, Mohsen Z. EI-Sherif, " Studying different types of power converters fed Switched Reluctance Motor" International Journal of Electronics and Electrical engineering, Vol.01, No.04, Dec. 2013, PP281-291.9.
5. Vashist Bist; Bhim Singh, "A Brushless DC Motor Drive With Power Factor Correction Using Isolated Zeta Converter" IEEE Transactions on Industrial Informatics,Year: 2014, Volume: 10, Issue: 4,Pages: 2064 -2072, DOI: 10.1109/TII.2014.2346689, IEEE Journals & Magazines
6. Najmeh Zamani; Mehdi Niroomand; Mohammad Ataei " Bifurcation and chaos control in power-factor-correction boost converter" 2014 22nd Iranian Conference on Electrical Engineering (ICEE), 2014, Pages: 1307 - 1312, DOI: 10.1109/IranianCEE.2014.6999736
7. Honglan Wu; Hongjuan Ge; Yuanyuan Xu; Wenbin Zhang, "The power factor correction of three-phase to single-phase matrix converter with an active power decoupling capacity" ,2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific),1 - 5, DOI: 10.1109/ITEC-AP.2014.6940742
8. R. Karthigayini; D. Gokilapriya "A bridgeless power factor correction using Cuk converter", International Conference on Green Computing Communication and Electrical Engineering(ICGCCEE),2014,Pages: 1to6, DOI: 10.1109/ICGCCEE.2014.6922353, IEEE Conference Publications.
9. Vashist Bist; Bhim Singh "Reduced sensor configuration of brushless DC motor drive using a power factor correction-based modified-zeta converter" IET Power Electronics, 2014, Volume: 7, Issue: 9, 2322 - 2335, DOI: 10.1049/iet-pel.2013.0177
10. Saijun Zhang; Richard Garner; Yuting Zhang; Shashank Bakre, " Quantification analysis of input/output current of interleaved power factor correction (PFC) boost converter" 2014, IEEE Applied Power Electronics Conference and Exposition - APEC 2014, 1902 - 1908, DOI: 10.1109/APEC.2014.6803565
11. Bhim Singh; Vashist Bist "A BL-CSC Converter-Fed BLDC Motor Drive With Power Factor Correction" IEEE Transactions on Industrial Electronics, Year: 2015, Volume: 62, Issue: 1, Pages: 172 - 183, DOI: 10.1109/TIE.2014.2327551.
12. P. Sarala, "Power Factor correction with current controlled Buck converter for BLDC motor Drive", IJPEDS, Vol. 08, No. 02, June 2017, pp 730-738, ISSN; 2088-8694, DoI;10.11591/ijpeds.

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