A DECISIVE EVALUATION OF SRM DRIVE FOR INDUSTRIAL APPLICATIONS WITH HIGH POWER FACTOR CORRECTION CAPABILITIES

P. Sridhar *, Dr. V Purna Chandra Rao ** and Dr. B P Singh***

* Department of Electrical & Electronics Engineering, Institute of Aeronautical Engineering, Hyderabad, INDIA
sridharp35@gmail.com
** Professor & Principal Jyothishmathi Institute of Technology & Science, Karimnagar, Telangana, India
***GM (Rtd), BHEL R&D, Director R&D, St. Martins Engineering College, Secunderabad, INDIA

ABSTRACT: In a three phased switched reluctance drive, the input DC voltage source is universally supplied by a circuit comprising of a diode bridge rectifier model and a capacitive filter interfaced to an AC line. The diode bridge rectifier absorbs distorted current from the AC line, which evolves the degraded power factor (PF) and system efficiency is very low. A three phased 6/4 SRM drive system is highlighted in this paper, which comprise the recognition of a drive circuit for the minimization of torque ripples and power factor enhancement with a decisive asymmetric switching topology. A unique switching topology for SR drive is confined by a closed loop control procedure. The validity of the proposed switching scheme is controlled by PI control design to attain favorable advantages, dynamically analyzed by Matlab/Simulink environment tool, the results are conferred.

KEYWORDS: Asymmetrical Converter, Harmonics, Proportional- Integral Controller, Power Factor Correction, Switched Reluctance Motor, Total Harmonic Distortion.

INTRODUCTION

Conversion of AC-DC electric power is widely preferred in many industrial applications like as adjustable speed drives (ASDs), uninterruptable power supplies (UPSs), switch-mode-power-supplies (SMPS), as well as battery energy storage systems (BESS). By formally, AC-DC conversion process is stated as rectifiers, and is developed by thyristor and diodes to afford controlled and uncontrolled DC power with the provision of uni-directional and bi-directional power flow as presented in [1]. The main determinant of poor power quality in the nature of distorted current injection results of poor power quality at source side parameters which may cause current/voltage distortions, large size AC/DC filter requirement to regulate the load side DC ripples, low efficiency. This would lead to electric power pollution at the distribution network.

Switched Reluctance Motor (SRM) is a singly excited doubly salient synchronous motor; construction is very simpler than all other electrical machines because of windings mounted on stator itself. The main advantage of this SRM is very simple in structure, robustness and less expensive, high fault tolerance condition, high torque/volume ratio; efficiency is appreciably flat over the wide speed range operations. Compare to BLDC motor, SRM need electronically commutated circuit because cannot run directly from the AC or DC bus. Due to the double saliency implementation of the SRM, necessary for the machine to generate reluctance torque tends to non-linear magnetic characteristics making it to difficult for controlling. Due to the combination of perceived awkward

With the SRM, the lack of commercially available semiconductor devices with which operate them. It is very reliable machine since each phase of the SRM is largely independent physically, electrically, magnetically from the other phases.

A number of power electronic converter topologies have been developed over the years exclusively for use in conjunction with SRM drives. An excellent review of numerous power electronic converter configurations for SRM drives is available for power factor correction as proposed in [2] as shown in Fig.1. SRM coupled inside a battery-charging circuit has been proposed in [3], and is a great decision for ease battery powered requisitions, as it joins

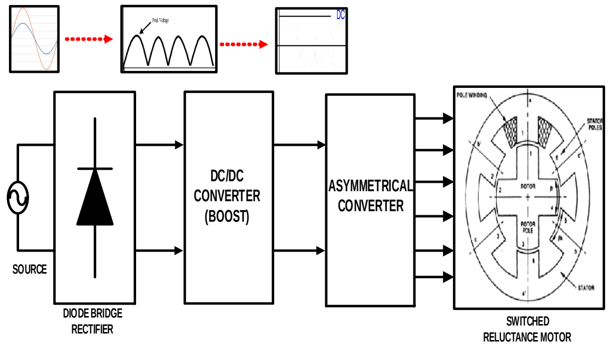


Fig.1 Schematic Diagram of Improved Power Factor Correction Technique

together high effectiveness and high unwavering quality with low assembling expenses is highlighted in [4]. Keeping in mind the end goal to legitimately control SRM, the stator excitation needs to be synchronized with the rotor position. A few position sensors identification systems have been created in the recent decades as proposed in [5] to supplant the costly and problematic physical position sensors. Mostly SRM drives have pivotal issues of enormous ripple content in torque due to absence of current in respective torque. However this should be alleviated to a high reputation of phase current covering.

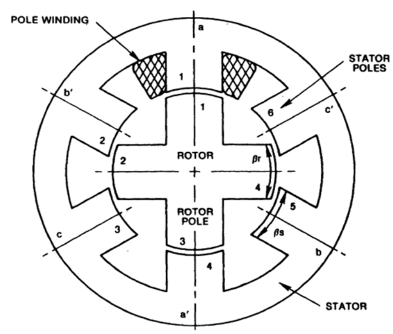


Fig. 2 Basic three phase 6/4 SRM

Subsequently, utilization of converters for support of SRM drives obliges individual control strategy for each individual phase in that torque ripples minimized by phase sequenced current progression methodology.

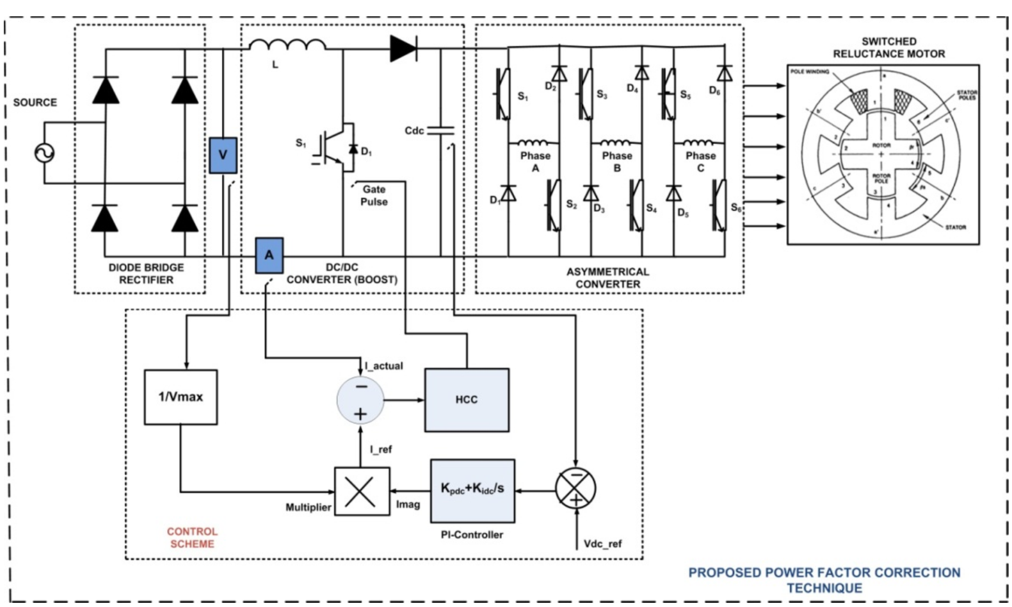


Fig.3 Closed Loop Control of SRM Drive System

This paper highlights the decisive converter topology for speed control of SRM drive configuration with enhanced power quality features. With a specific end goal to get the great transient reaction, the general proposed system is executed in closed loop setup using the proportional-integral controller. Computer simulations are performed for dynamically evaluation of SRM drive system and results are conferred with low THD values.

PRINCIPLE OPERATION OF SRM

Switched Reluctance Motor has wound field coil nature of a dc machine for its stator windings and it has no magnetic things on its rotor. Both the stator and rotor have remarkable shafts, henceforth the machine is alluded to as a doubly striking/salient machine. SRM are made by covered with rotor & stator cores with Ns=2mq shafts on the rotor as well as stator poles, number of phases is m & each and every phase is to be designed by focused coils put on 2q stator poles. Most supported setup amongst numerous choices are 6/4 three phase and 8/6 four phase Switched Reluctance Motor's as indicated in the Fig 2. These two setups relate to q = 1(one sets of stator poles and coils for every phase) however q may be equivalent to 2 or 3 additionally. With standout phase switched on; the rotor will be very still in a position which gives least reluctance to the flux generated by that following phase. In this position, there won't be any created torque on the rotor. Presently, if that stage is exchanged off and an alternate stage exchanged on; the rotor encounters a torque having a tendency to move it to a base reluctance position, comparing to the new phase one [7]. Whichever heading of development offers the slightest separation to be moved by the rotor to achieve the new least reluctance position is the course of rotor movement, and the outflow for the torque is followed as

$$T_e = \frac{dL(\theta,i)}{d\theta}\frac{i^2}{2} \qquad (1)$$

Design of 6/4 SRM Drive

This is valid for all SR converter circuits on the grounds that are dependably a motor winding arrangement with every principle power exchanging device. Second, there is a more terrific level of freedom between the phases and is conceivable expected ac or brushless dc drives. Among those converters, the a-symmetrical power converter is the most famous and best-performed one, in which each phase branch comprises of two discrete switching parts and two free-wheeling diodes, as indicated in Fig 3. When the concerned switches S1 & S2 are move to turn ON, then phase A is energized. When the specific switches are S1 and S2 are to be turned OFF, the operating diodes D1 & D2 are conducting from the closed circulation mode. In this mode phase A is de-energized. For getting fast transient response, the overall drive system is implemented in closed fashion; same control principle is used for this 6/4 SRM-drive as depicted in Fig.3, it represents the overall control scheme with proposed SRM drive topology

The proposed scheme demonstrates the closed-loop control execution of SRM drive framework with embraced control scheme. The reference voltage that is normal at the direct driven for boosted converter & the real outcome of boosted converter is proposed in [9]. The respective voltage-controller forms the indicating the failure things and supports efficient current gain value. This actual current signal is in product with unit sine-layout it should be evaluated by utilizing PLL circuit. The reference load current is subtracted from actual component to be handle-over the reference signal generation. Then the boost inductor current cannot be substituting, unquestionably the circuit gives assured estimation of reference current indication is given to the current controlling component to generate the optimal gating pulses. The hysteresis current controller embraced the upper as well as lower band are made by including & subtracting a band 'h' with the reference signal which may create the obliged gating sequences for moving the dc voltage with in high stability factor and enhance power factor component at source terminals.

RESULTS& DISCUSSIONS

Here simulation is carried out in different cases, in that
1) Conversion of AC/DC without & with DC link Capacitor. 2) AC/DC Conversion with DC/DC Converter 3) Proposed Open Closed Loop Control of 6/4 SRM Drive.4) Proposed Closed Loop Control of SRM Drive Applications to Power Factor Correction Technique.

Case 1: Conversion of AC/DC with & without DC Link Capacitor
Fig.4 shows the Matlab/Simulink model of proposed AC/DC Conversion with & without DC-Link Capacitor using Matlab/Simulink Platform. Conversion of AC-DC supply by using bridge manner of rectifier topology with the help of uncontrolled switch such as diode may convert the AC to constant DC from a AC line, as well as load preference goes to R-load condition, which makes to support load side power factor should be maintained as unity.

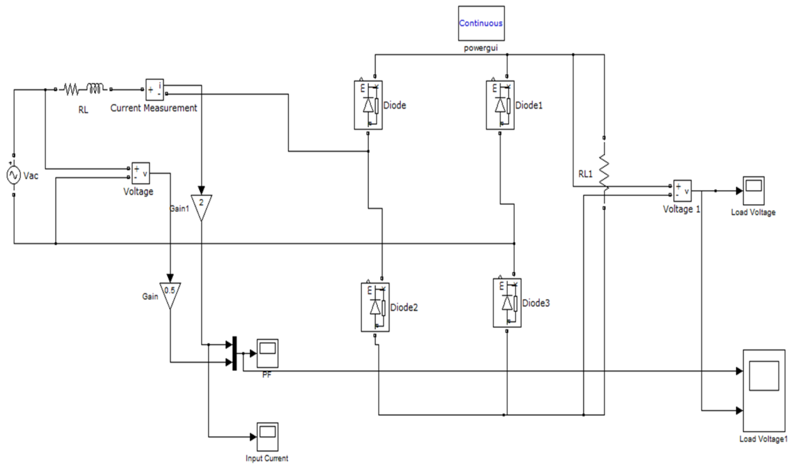


Fig.4 Matlab/Simulink Model of Conversion of AC/DC with & without DC Link Capacitor

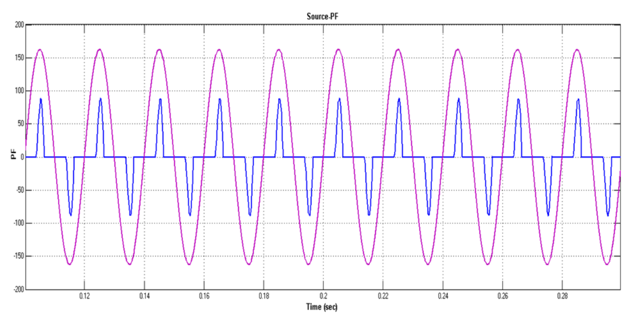


Fig.5 Source Power Factor of AC/DC conversion with Load Side Filter

Fig.5 Source Side Power Factor of AC/DC conversion with Load Side Filter, need of load side filter to get constant DC output voltage, presence of high rated capacitive filters some more distortions in source side current, power factor at this moment is other than unity

Case 2: AC/DC Conversion with DC/DC Converter

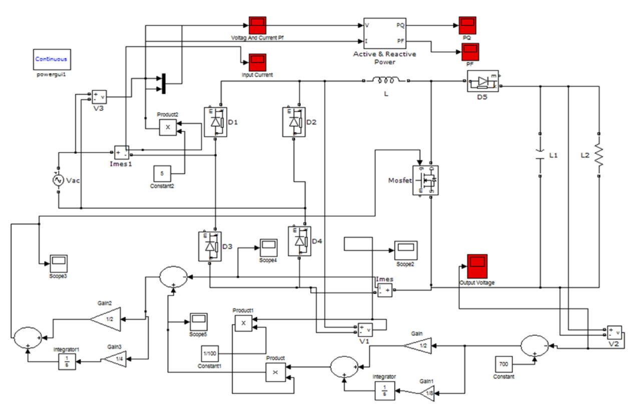


Fig.6 Matlab/Simulink Model of AC/DC conversion with DC/DC Converter

Fig.6 shows the Matlab/Simulink Model of AC/DC conversion with DC/DC Converter using Matlab/Simulink Platform. Here utilization of high voltage gain DC/DC converter operated under continuous conduction mode (CCM) to be controlled by closed loop manner with respect to load achievement & improvement of source side parameters and minimize the load side DC ripples.

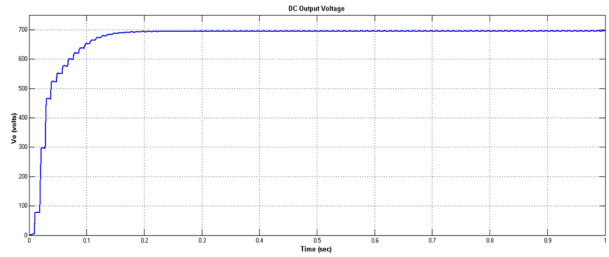


Fig.7 Load Voltage of Proposed AC/DC conversion with DC/DC Converter

Fig.7 shows the Load Voltage of Proposed AC/DC conversion, in that no need of any load side filter gets constant DC. With closed loop feedback control of DC/DC converter maintained output voltage as a constant nature with respect to any load disturbances, controlled by using voltage controller with respect to reference value and actual value get some steady state error controlled by this control loop, as above fig represents the dynamic response of DC/DC converter output voltage as constant value.

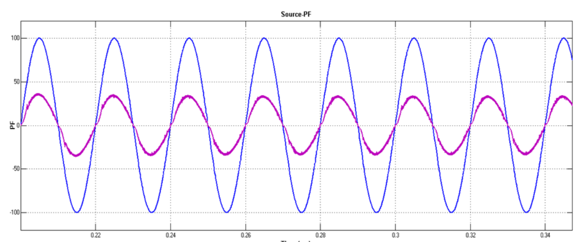


Fig.8 Source Side Voltage & Current

Fig.8 Source side voltage and current of AC/DC conversion with DC/DC converter, no need of load side filter to get constant DC output voltage as well no distortions present in source side parameters then both source voltage & current will be in phase condition. Use of high voltage gain DC/DC converter topology get constant output DC voltage and no need of encourage any load side filters, power maintained as a quality nature with-in the standards, both voltage & current to be maintained as in-phase nature.

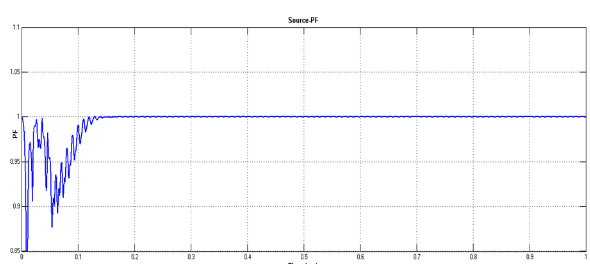
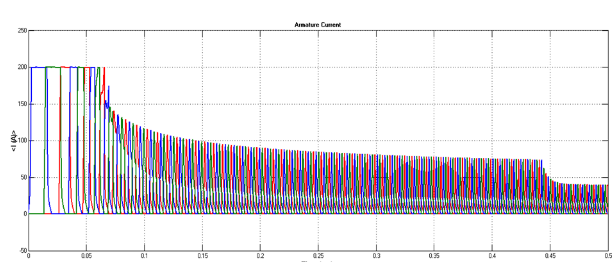


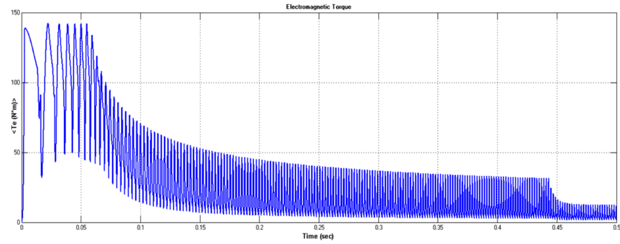
Fig.9 Source Power Factor of AC-DC Conversion with DC-DC Converter

Fig.9 Source Power Factor of conversion of AC-DC with DC-DC Converter, power factor maintained as constant to be corrected and as before condition drop to 0.6 lag condition and improved nearby unity condition.

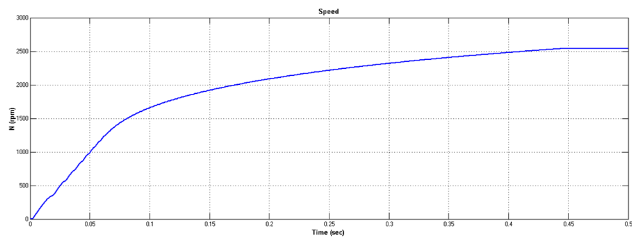
Case 3: Proposed Closed Loop Control of 6/4 SRM Drive



(a) Armature Current



(b) Electromagnetic Torque



(c)Speed

Fig.10 Current, Electromagnetic Torque, Speed of Proposed Closed Loop Model of 6/4 SRM Drive Configuration

Fig.10 shows the Current, Electromagnetic Torque, and Speed of Proposed Closed Loop Model of 6/4 SRM Drive Configuration, due to closed loop circuit achieve fast response with low steady state error. No delay to achieve steady state condition, need 0.23 sec time to get steady state response because of error free and system may operate in more stable condition is attained.

Case 4: Proposed Closed Loop Control of SRM Drive Applications to Power Factor Correction Technique

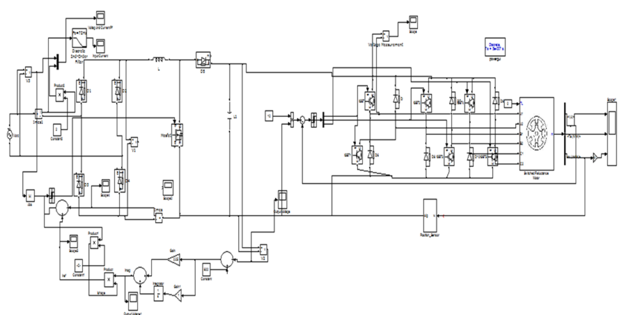


Fig.11 Matlab/Simulink Model of Proposed Closed Loop Model of 6/4 SRM Drive Configuration Applications to PFC

Fig.11 Matlab/Simulink Model of Proposed Closed Loop Model of 6/4 SRM Drive Configuration applications to PFC using Matlab/Simulink Software Package. This SRM drive comprises of power semiconductor devices, position sensors, as well as high level controller. The power semi-conductor device energizes the windings of SRM drive and it may controlled by voltage controller. The utilization of position sensor supports the position of rotor angle for synchronizing the excitation of phase with imperative rotor positioned device.As above Fig.11 depicts the single phased voltage doubling converter topology feeding asymmetrical converter of SRM drive. The main focal point of this configuration is that it may inject harmonics into AC supply side with a very low power factor at input side. To enhance power quality features at AC source side of SRM drive, a PFC converter methodology is required at front side of SRM drive.

Fig.12 shows the Source Power Factor of Proposed Scheme with DC/DC converter fed asymmetrical converter with SRM drive, due to the proposed converter topology source current comes as pure sinusoidal with constant DC output voltage with respect to supportive action of voltage controller with concern gain values get smart response of source parameters with the valuation of low THD in source currents, then both the terms will be placed in-phased operation and improve the power quality features.

Fig.13 shows the Current, Electromagnetic Torque, and Speed of Proposed Closed Loop Model of 6/4 SRM Drive Configuration with PFC, due to closed loop circuit achieve fast response with low steady state error and improve the PF at source side.

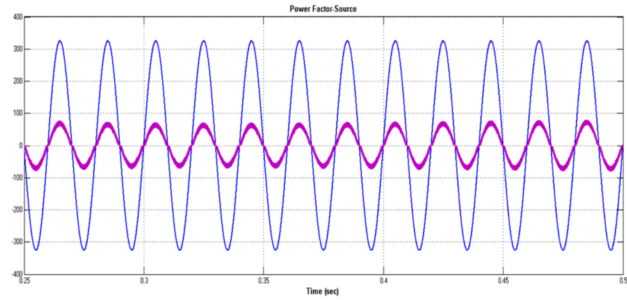
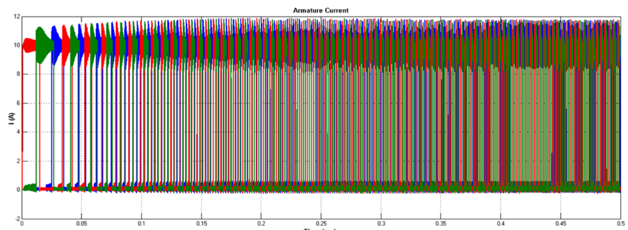
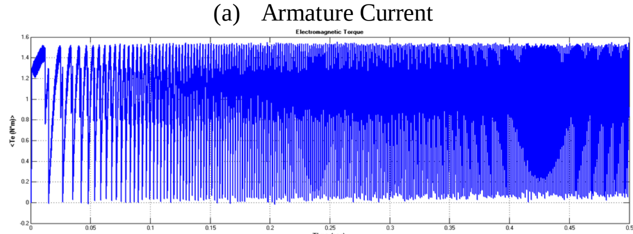


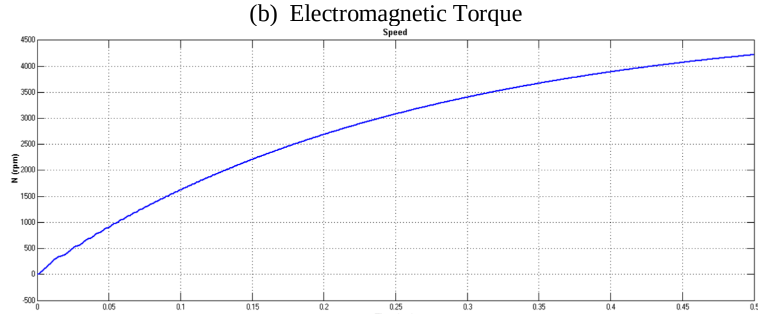
Fig.12 Source Power Factor of Proposed Scheme with DC/ DC Converter Fed Asymmetrical Converter with SRM Drive



(a) Armature Current



(b) Electromagnetic Torque



(c) Speed

Fig.13 Current, Electromagnetic Torque, Speed of Proposed Closed Loop Model of 6/4 SRM Drive Configuration with PFC

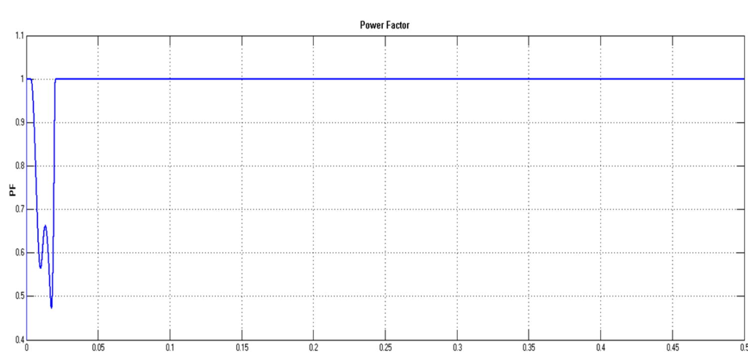


Fig.14 Source Power Factor of AC/DC conversion with DC/DC Converter Fed SRM Drive

Fig.14 Source Power Factor of AC/DC conversion with DC/DC converter Fed SRM Drive, power factor maintained as a constant and improved nearby unity condition.

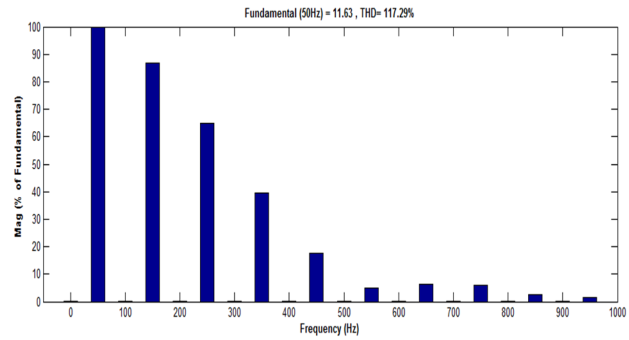


Fig.15 THD Analysis of Source Current with DC Link Capacitor (Before Power Factor Correction)

Fig.15 depicts the THD analysis of source current with specific capacitor, get 117.29% out of IEC standards. As below Fig.27 shows the THD analysis of source current with proposed DC/DC converter fed SRM drive; get 1.59% within IEC standards. Currently measuring the harmonized values using Fourier analysis, here used FFT analysis for optimal evaluation of harmonic frequencies may presence in source current as above specified with & without DC link filter, before power factor correction received 117.29% as THD value at fundamental component as per IEEE standards THD will be less than 5%, here optimizing the THD response of source current using voltage doubling DC/DC converter topology without no need of filter, then THD response after compensation 1.59% as depicted in below fig. 16.

Table 1. Comparative Analysis of Source Current THD responses with DC link capacitor& with proposed PFC methodology

SL.NO	THD (%)	With DC Link Capacitor	With Proposed PFC Methodology
01	Source Current	117.29%	1.59%

As, table I shows the comparative analysis of source current THD responses with DC Link capacitor & with proposed PFC methodology, due to this load side DC link filter get THD response as 117.29%, by using proposed PFC method pertaining source current THD drastically goes to reduces, well within IEEE standards.

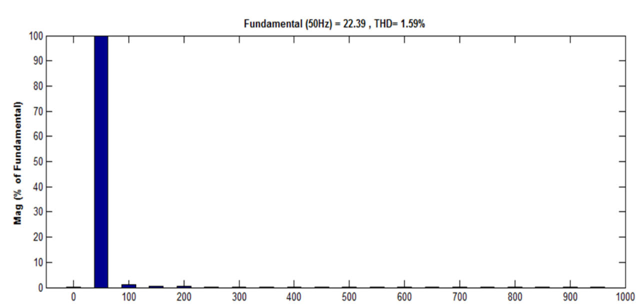


Fig.16 THD analysis of Source Current with proposed DC/DC converter fed SRM drive (After Power Factor Correction)

Fig.17 shows the Voltage, Current, Power Factor, Change in Speed, Phase Current, Speed of Proposed Closed Loop Model of 6/4 SRM Drive configuration operated under N=4000 rpm, due to closed loop control maintained as constant speed with low steady state error. Performance evaluation of symmetrical converter topology fed SRM drive with front end power factor correction technique operated under variable speed condition, due to sudden change of load, significantly speed disturbs at particular point in high speed applications within a certain limits may controlled by using closed loop sensing device and regulate the particular system speed by attaining the respective gain factor of voltage controller within a followed error coming from summing action control over the speed, voltage across converter based on this control action it will be operated under certain speed range with high power as well as high speed applications and merely preferred by many more industrial applications as well as residential applications, for this 4000 rpm speed, pertaining THD value is 2.43% and operated under 0.99 lagging power factor region.

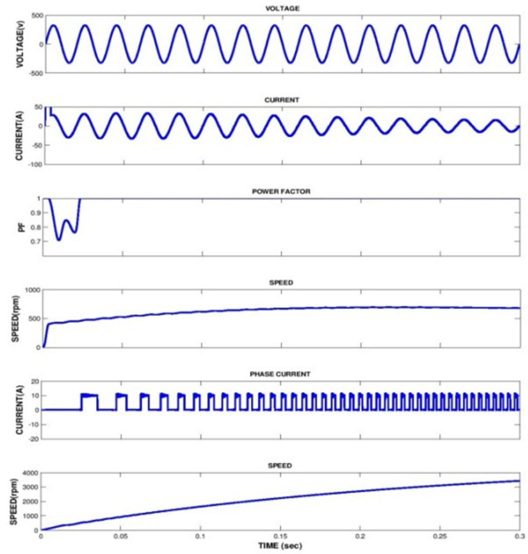


Fig.17 Voltage, Current, Power Factor, Change in Speed, Phase Current, Speed of Proposed Closed Loop Model of 6/4 SRM Drive Configuration operated under N=4000 rpm

Table 2. Comparison Analysis of Closed Loop Control of SRM drive with PFC Capability

Sl. No	Speed (rpm)	Power Factor	THD (%)
01	3000	0.999	2.43%
02	3500	0.998	2.43%
03	4000	0.999	2.43%
04	5000	0.998	2.42%
05	6000	0.999	2.43%

As Table 2 shows the comparative analysis of closed loop control of SRM drive with improving power factor as well as total harmonic distortion, here consider several speed ranges for updating the proposed methodology due to change of speed variants operated as a stable condition with respect to IEEE/IEC standards.

CONCLUSION

Switched Reluctance Motor (SRM) has turned into an aggressive determination for some requisitions of electric machine drive frameworks as of late because of its relative basic development and its robustness. This paper highlights the diode bridged rectifier (DBR) based converter is secured to adjust the input current of the drive, enhancing the power factor of SRM drive. Dc link capacitors dispensing and subsequently making proficiency of proposed DC/DC converter topology with sustained SRM is attained by utilizing deviated converter. The source current recurrence spectra unmistakably delineate current THD improvement as inside the IEEE/IEC standards through power factor correction. Utilization of closed-loop control with PI controller with K_p and K_i gain values are proposed in this paper for accomplishing quick reaction, low consistent steady state error and low torque ripples. Closed-loop controller for SRM drive with power factor redress is executed in Matlab/Simulink environment.

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