International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.6., 2015
(Nov.-Dec.,)

RESEARCH ARTICLE

ISSN: 2321-7758

IMPROVEMENT OF POWER FACTOR WITH BATTERY CHARGING CAPABILITY FOR SRM DRIVE USING CSR

MOHAMMED AZAHAR AHMED, MUZEEB KHAN PATAN, B VENKATA KRISHNA, B.S.S.SANTOSH
DEPARTMENT OF ELECTRICAL ENGINEERING, SRKR ENGINEERING COLLEGE.

MOHAMMED AZAHAR AHMED

MUZEEB KHAN PATAN

ABSTRACT

This paper proposes a two stage power converter which involves current source rectifier (CSR) to improve the power factor of switched reluctance motor (SRM) drives and facilitating a battery to charge while SRM is operated in regenerative mode. The second stage involves SRM converter which is fed by CSR stage. Necessity of Dc link's capacitor is negligible and create the capability of energy saving in regenerative mode of SRM drives. The Space Vector Modulation (SVM) is used in the CSR switching. Proposed two-stage power converter validation through significant reduction of the THD value of the supply current with line drawn current quality and power factor improvement are evaluated. Theoretical analysis of this strategy is presented in this paper with simulation results.

Key Words: Power factor, CSR (Current Source Rectifier), THD (Total Harmonic Distortion), Regenerative mode, SVM (Space Vector Modulation)

INTRODUCTION

With the advent of SRM there is a rapid advance in the field of variable speed drive applications due to inexpensive, high power switching devices and has copious number of advantages. The rotors have no windings or magnets resulting less losses and increased efficiency, negligible mutual coupling, higher or comparable reliability due to fault tolerant robust structure and economic [1].

The major problems associated with switched reluctance motor drive system are low operating power factor, torque ripple which results in undesirable vibration and acoustic noise. Usually these torque ripples are nullified either by motor design or by suitable control methods [4]. Power factor maintenance stands as one of the stumbling blocks for every electrical engineer and improving it is essential to enhance their sustainability. In general low power factor can increase power distribution system loses.

In the above mentioned strategy power factor is improved by using a two stage power converter based on current source rectifier (CSR) as an input stage of the asymmetrical converter [8]. Here front-end large filter capacitor helps the battery to charge in regenerative mode of SRM [7].

Previously introduced SRM converter includes a front end large filter capacitor and diode bridge rectifier which results in low power factor (PF). This conventional SRM fails in various aspects like high current harmonics and drawing a pulse current from ac source side which makes the system less efficient. A partial load say battery charging circuit is coupled to the SRM which has been proposed and stands as low cost battery powered applications constituting high efficiency and high reliability at optimal cost.

The THD value of the supply current with line drawn current quality is significantly reduced and power factor improvement are evaluated by computer simulations with MATLAB/Simulink.

SWITCHED RELUCTANCE MOTOR DRIVE: -

Switched Reluctance Motors (SRM) have inherent advantages such as simple structure with non-winding construction in rotor side, safe because of its characteristic which has a high tolerances, robustness, low cost with no permanent magnet in the structure, and possible operation in high temperatures or in intense temperature variations [6]. The torque production in switched reluctance motor comes from the tendency of the rotor poles to align with the excited stator poles. The operation principle is based on the difference in magnetic reluctance for magnetic field lines between aligned and unaligned rotor position when a stator coil is excited, the rotor experiences a force which will pull the rotor to the aligned position. However, because SRM construction with doubly salient poles and its non-linear magnetic characteristics, the problems of acoustic noise and torque ripple are more severe than these of other traditional motors. The phase current commutation is the main cause of the torque ripple.

The torque ripple can be minimized through magnetic circuit design in a motor design stage or by using torque control techniques. In contrast to rotating field machines, torque control of switched reluctance machines is not based on model reference control theory, such as field oriented control, but is achieved by setting control variables according to calculated or measured functions.

CONSTRUCTION OF SRM:

The Switched Reluctance Motors is an electric machine that is characterized mainly by its constructive simplicity. It has salient poles on both stator and rotor and its magnetic core consists of laminated steel. It is a doubly salient, single excited motor. The schematic diagram of an SRM with eight stator and six rotor poles is shown in Fig 1 The stator windings on diametrically opposite poles are connected in series to form one stator phase. For very high speed application, Cobalt-iron and variants are used for laminations. The stator and rotor poles appear in pairs but are usually of unequal numbers. This is to avoid the eventuality of the rotor being in a state of producing no initial torque, which occurs when all the rotor poles are locked in with the stator poles feature of SRM is that it can be operated, even though with reduced power output, even when there is a loss of one of the phases to reduce the number of switching devices and the associated commutation, the torque Different configurations have been studied and its influence on the performance has been reported. In order to guarantee that the SRM can be started at any initial rotor position, and to get smooth torque capacity per resolution, SRM's with multi-phase as well as multi-rotor-pairs are developed. The number of stator and rotor poles is generally different. Some possible combinations are: N_s = 6, N_r = 4; N_s = 8, N_r = 6; N_s = 12, N_r = 10, etc. By choosing a combination where there are two more stator poles than

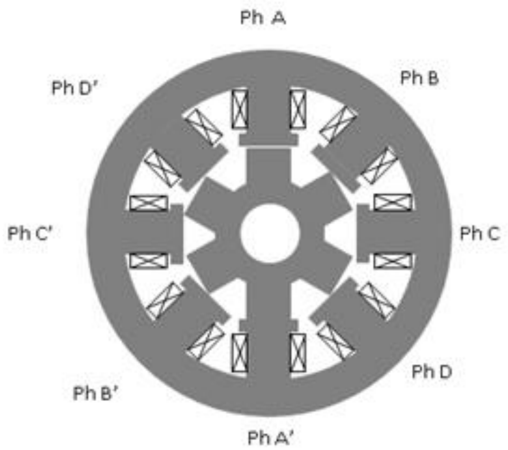


Fig1: Cross section of a 8/6 SRM

rotor poles, high torque and low switching frequency of the power converter can be achieved. Three phase 6/4 pole and four phase 8/6 pole configurations are popular among different configurations.

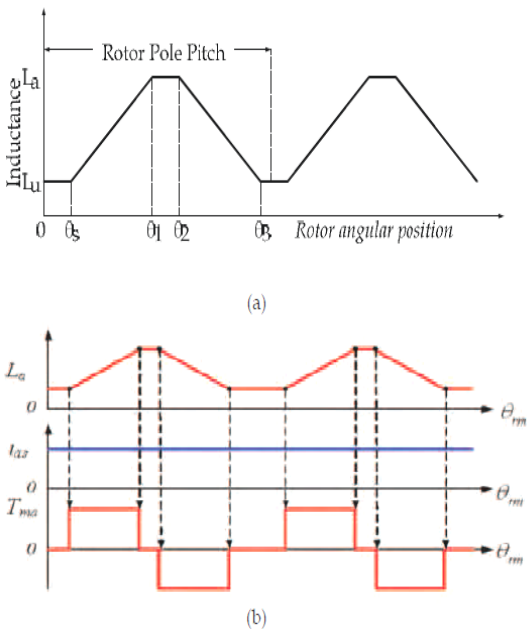


Fig2: Inductance and torque in SRM

BASIC COMPONENTS OF SRM CONVERTER:

Block diagram of a conventional SRM converter is shown in Fig.3 It can be divided into: utility, AC/DC converter, capacitor network, DC/DC power converter and SR motor.

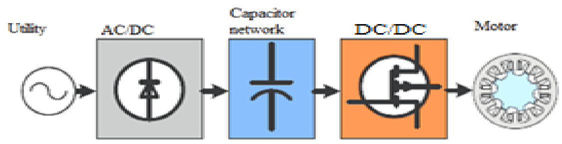


Fig3.Component block diagram of conventional SRM drive

The converter for SRM drive is regarded as three parts: the utility interface, the front-end circuit and the power converter as shown in Fig.4. The front-end and the power converter are called as SR converter. The converter should have resonant circuit to apply zero-voltage or zero-current switching for reducing switching loss.

The conventional SRM drive with unipolar power converter is shown in the above fig4. The drive circuit has a three phase diode rectifier, a bulk dc link capacitor and an asymmetric bridge converter. Conventional SRM drive is very simple, but the capacitor charges and discharges, which draws a pulsating ac line current, and results in a low power factor. The low power factor of the motor increases the reactive power of the power line and decreases efficiency of the drive system.

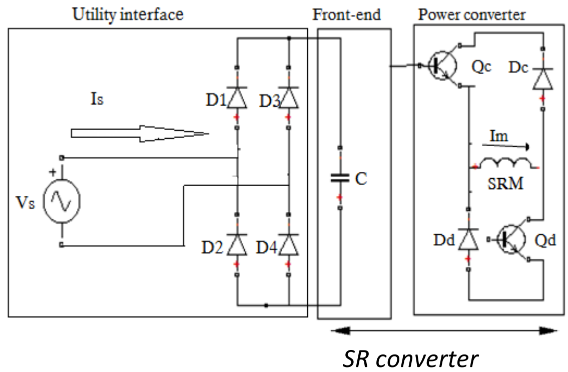


Fig.4. Conventional modules of SRM Drive

PROPOSED SRM DRIVE

SRM is something which is rapidly advancing in the field of variable speed drive applications and possesses many distinguished merits. Proposed two-stage converter can be seen in Fig 5. Front end converter in first stage is placed as controllable rectifier diodes with advantage of improving low power factor and eliminating high input line harmonics (Current Source Rectifier) [7]. Phase winding energizing is done by machine side converter as second stage [2, 5]. The CSR in modified SRM drive have six bidirectional self-commutated switches. No short circuit must be applied to the mains filtering capacitors and No open circuit must be applied to the output current.

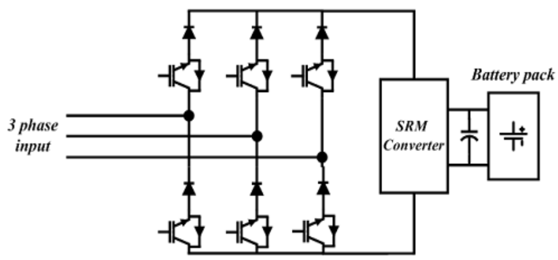


Fig 5: Proposed SRM drive.

The resulting output line-voltage space vector defined by:

$$\overline{Vol} = vAB(t) + \bar{a}.vBC(t) + \overline{a^2}.vCA(t)$$

Where $\bar{a} = 1\angle 120^0$. The switching technique applied to the CSR is space vector modulation (SVM)

Vol.3., Issue.6., 2015
(Nov.-Dec.,)

expressing the required instantaneous input current vector according to the voltage vector. Unit power factor will be achieved through this approach. The switching state vectors duty cycles are:

$$d_\mu = {T_\mu}/{T_S} = m_c \cdot \sin(60^\circ - \theta_{sc}),$$
$$d_\upsilon = {T_\upsilon}/{T_S} = m_c \cdot \sin(\theta_{sc}),$$
$$d_{0c} = {T_{0c}}/{T_S} = 1 - d_\mu - d_\upsilon$$

Where mc is the modulation index, TS is the sampling interval and θsc is the angle between the reference vector and the first active vector [3].

In this setup dc link capacitor can be used to charge a battery in regenerative mode of SRM drive. Fig 6 shows the regenerative mode operation of SRM drive. The turn off and turn on angles affect dc link current ripple and rms value.

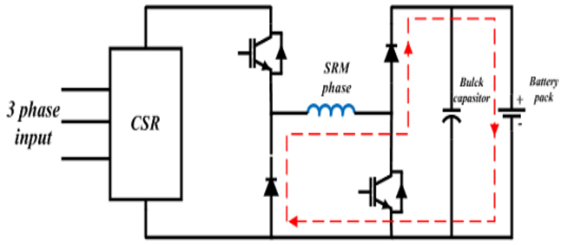


Fig 6: Regenerative mode operation of SRM.

SIMULATION AND EXPERIMENTAL RESULTS

The desired results are extracted and observed in simulation. Usually the SRM drive system is carried out on partial loads. The current control is implemented by a closed-loop control with hysteresis switching control of the converter.

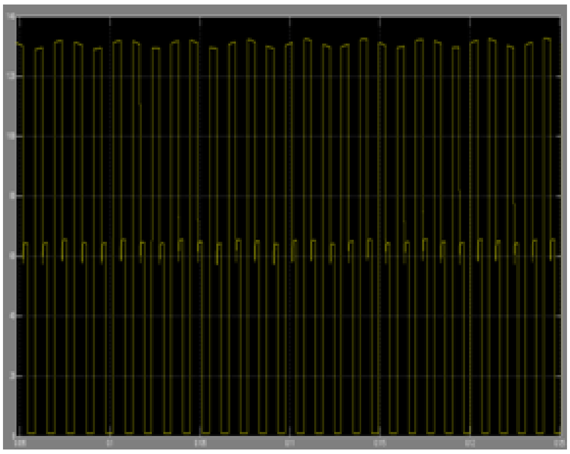


Fig 7: phase voltage waveform of SRM

Position sensor is used to track SRM's rotor alignment

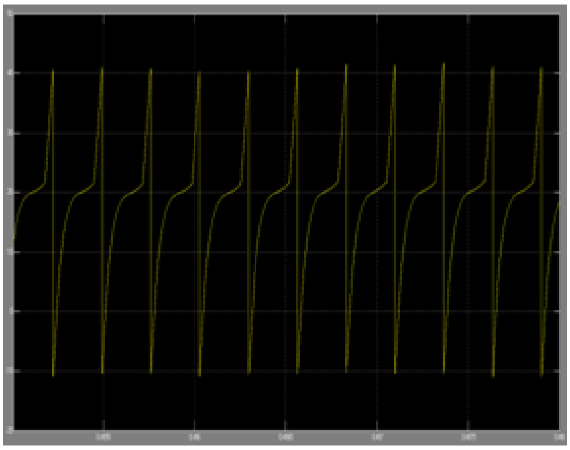


Fig 8: phase current waveform of SRM

The output voltage waveform of CSR shows clearly six order harmonics riding over a dc voltage. The waveform is very similar to a conventional three phase diode bridge output with chopping. High frequency harmonics can be eliminated with a small size capacitor in dc link.

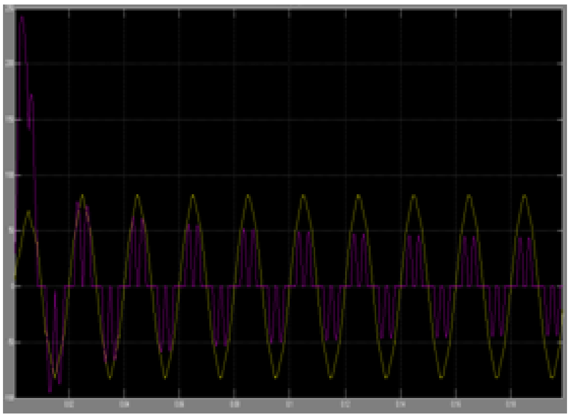


Fig 9: Input voltage & current waveforms of conventional SRM drive

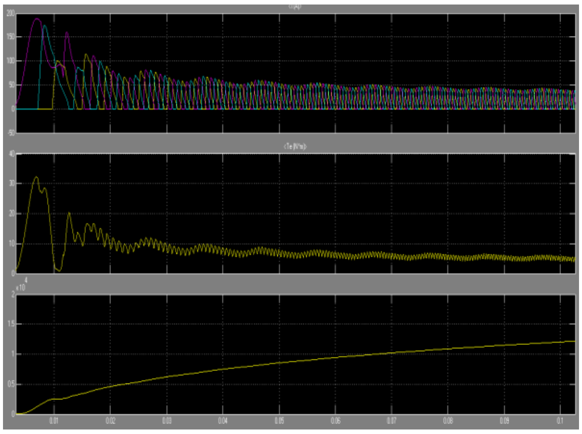


Fig 10: Output responses of conventional SRM drive (I v/s t, T v/s t, w v/s t)

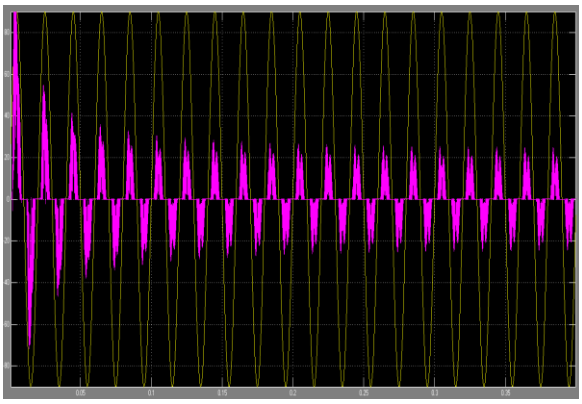


Fig 11: Input current & voltage waveform of proposed SRM drive

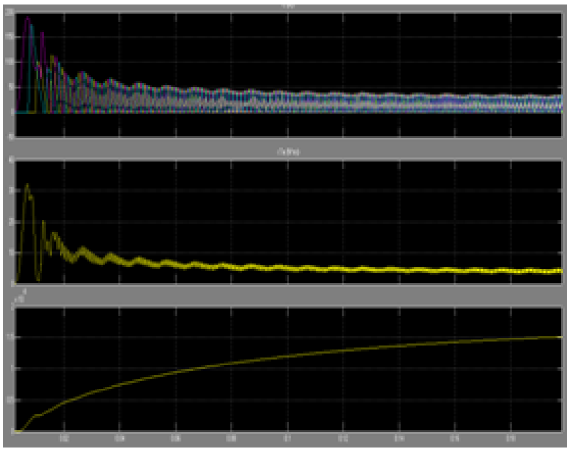


Fig 12: Output responses of proposed SRM drive (I v/s t, T v/s t, w v/s t)

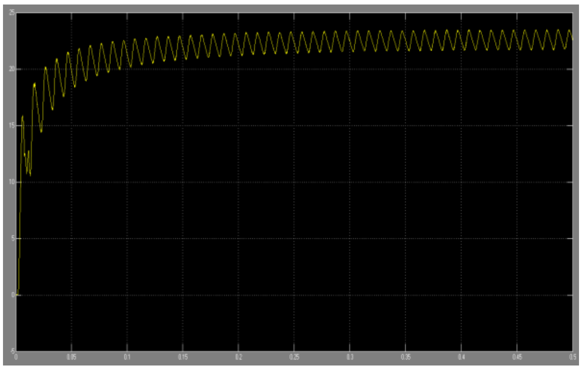


Fig 13: Battery charging current waveform

Battery pack current for fixed angle control of SRM is shown in Fig. 10. Turn on and turn off Angles control ripple, RMS and average value of dc link current.

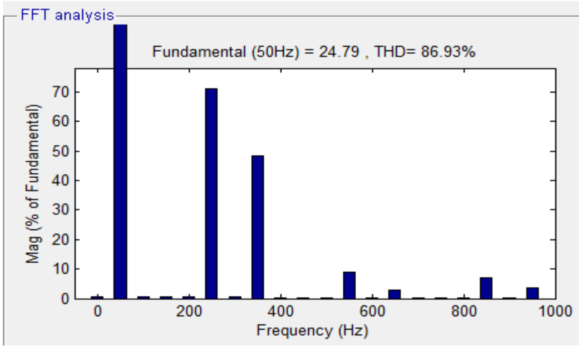


Fig 14: Spectra of input line current waveform of SRM drive without CSR

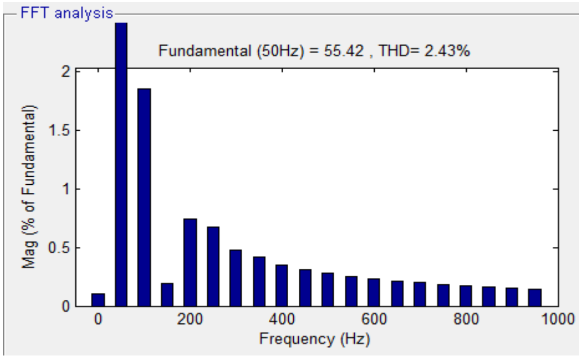
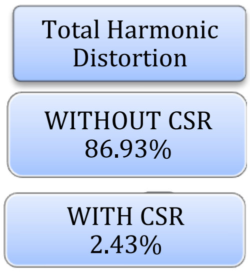


Figure15: Spectra of input line current of SRM drive with CSR

CONCLUSION:

A CSR based converter is established to modify the input current of the drive, improving the power factor of SRM drive. By eliminating Dc link's capacitors capability of energy saving in regenerative operation mode of SRM is achieved by CSR based converter. The input phase current frequency spectra clearly illustrate current THD improvement through power factor correcting. As an application, front-end large filter capacitor can be used to battery charging in regenerative mode of switched reluctance motor. The switching topology and control algorithm is implemented on simulink model of SRM.



REFERENCES

[1]. R.Krishnan, Switched Reluctance Motor Drives, Boca Raton, FL: CRC Press, 2001.

[2]. R. Krishnan, G. H. Rim, Modeling, "Simulation an Analysis Of variable Speed Constant Frequency Power Conversion Scheme with A Permanent Magnet Brushless DC Generator," in Proc. 1988 IEEE Industrial Electronics Society Conf, IECON, pp. 332 – 337.

[3]. H.R. Karshenas, J. Mousavi, "A new direct sinusoidal input/output acac converter with unidirectional switches", in Proc. 2008 IEEE Electrical Machines and Systems Conf, pp. 1885–1890.

[4]. M. Cacciato, A. Consoli, G. Scarcella and G. Scelba, "A switched reluctance motor drive for home appliances with high power factor capability," in Power Electronics Specialists Conference - PESC 2008, Jun 15-19, 2008, pp. 1235 – 1241.

[5]. L. Huber and D. Borojevic, "Space Vector Modulated Three-Phase to Three-Phase Matrix Converter with Input Power Factor Correction,"IEEE Trans. Industry Applications, vol. 31, no. 6, pp. 1234-1246, Nov/Dec. 1995.

[6]. S. Narla, Y. Sozer, and I. Husain, "Switched Reluctance Generator Controls for Optimal Power Generation and Battery Charging" IEEE Trans. Industry Applications, vol. 48, no. 5, pp 1452-1459, Sep./Oct. 2012.

[7]. P. Zhang, P. A. Cassani, and S. S. Williamson, "An Accurate Inductance Profile Measurement Technique for Switched Reluctance Machines," IEEE Trans. Industrial Electronics, vol. 57, no. 9, pp 2972-2979, Sep. 2010.

[8]. W. K. Thong and C. Pollock, "Low-Cost Battery-Powered Switched Reluctance Drives with Integral Battery-Charging Capability," IEEE Trans. Industry Applications, Vol. 36, No. 6, pp 1676-1681, Nov./Dec. 2000.

Brief Bio of Authors

MOHAMMED AZAHAR AHMED received B.Tech degree from NIMRA College of Engineering & technology. He has received M.E Degree from Andhra University College of Engineering And Technology. His Research area includes Automatic generation control using FACTS and non-linear controllers. He is currently working as a Assistant Professor in SRKR Engineering college, Bhimavaram.

MUZEEB KHAN PATAN received B.Tech degree from Lakkireddy Balireddy College of Engineering. He has recieved M.Tech Degree from Anurag Group of Institutions in Power Electronics & Electrical Drives. His research area includes Electrical Vehicles Control & design, Hybrid EV, Power Drives. He is currently working as an Assistant Professor in SRKR ENGINEERING COLLEGE, BHIMAVARAM.

B VENKATA KRISHNA received B.E degree from S.R.K.R. Engineering College. He has received M.Tech Degree from JNTU Kakinada in High voltage engineering. His research area includes high voltage testing and insulation co-ordination. He is currently working as an Assistant Professor in SRKR Engineering College, Bhimavaram.

B.S.S.SANTOSH received B.Tech degree from VISHNU Engineering College. He has received M.E Degree from S.R.K.R. ENGINEERING COLLEGE in PSA. His research area includes microgrids. He is currently working as an Assistant Professor in SRKR Engineering College, Bhimavaram.