POWER FACTOR IMPROVEMENT USING CURRENT SOURCE RECTIFIER WITH BATTERY CHARGING CAPABILITY IN REGENERATIVE MODE OF SRM

M.Rajesh[1], M.Sunil Kumar[2]

[1]P.G.Student, [2]Asst.Prof, Dept.of Eee, D.V.R & Dr.H.S Mic College of Tech, Kanchikacharla

ABSTRACT

In this paper, a two-stage power converter based on current source rectifier (CSR) is proposed to improve the power factor of Switched Reluctance Motor (SRM) drives and Battery Charging Capability in Regenerative Mode. CSR stage in the input of SRM converter, eliminate dc link's capacitors and create the capability of energy saving in regenerative operation mode of SRM drives. The space-vector modulation (SVM) is used in the CSR switching. The validity and effectiveness of the proposed approach is shown by simulation, also it is verified experimentally by using a laboratory 4-KW SRM setup based on TI TMS320F2812 platform. The results demonstrate a good agreement with the required conditions

I. INTRODUCTION

Power electronic converters can be broadly classified as AC-DC, AC-AC, DC-AC and DCDC converters. The focus of the work presented in this thesis is in the AC-DC conversion area. Most AC-DC converter applications desire a constant DC output voltage which will be further used for other purposes. Till very recently the attention of all manufacturers and users of AC-DC converters was on the DC side of the same. In this sense, the most popular AC-DC converter is the rectifier with C filter at lower power levels and the phase-controlled rectifier with LC filter at higher power levels. Currently, the concern in rectifiers include power quality issues relating to the source end as well. The reason for this is the undesirable AC line current harmonics drawn from the utility by the standard rectifiers. The presence of harmonics in the line current results in the distortion of the voltage at the Point of Common Coupling (PCC) due to the presence of source inductance. This may cause malfunction of other loads, power system protection and monitoring devices. Some of the other problems caused by line current harmonics are, overheating of the neutral line, interference with communication and control signals etc. With presence of lower-order harmonics in input current, power factor comes down. Poor power factor of operation implies interactive use of the volt-ampere rating of the utility equipment.

The power factor is defined as the ratio of the average power to the apparent power at an AC terminal. Assuming an ideal sinusoidal input voltage source, the power factor can be expressed as the product of two factors, the distortion factor and the displacement factor. The distortion factor kd is the ratio of the fundamental root-mean-square (RMS) current to the total RMS current. The displacement factor kq is the cosine of the displacement angle between the fundamental input current and the input voltage.

$$PF = K_d \ K_\theta$$

$$K_d = \frac{I_{rms(1)}}{I_{rms}}$$

$$K_\theta = cos\theta$$

Power factor correction is the method of improving the power factor of a system by using suitable devices. The objective of power factor correction circuits is to make the input to a power supply behave like purely resistive or a resistor. When the ratio between the voltage and current is a constant, then the input will be resistive hence the power factor will be 1.0.

II. SWITCHED RELUCTANCE MOTOR

Switched Reluctance Motors (SRM) have inherent advantages such as simple structure with non-winding construction in rotor side, fail 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. 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 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. Each stator pole has a simple concentrated winding and there are no conductors of any kind on the rotor which makes the construction cheaper, reliable, and rugged.

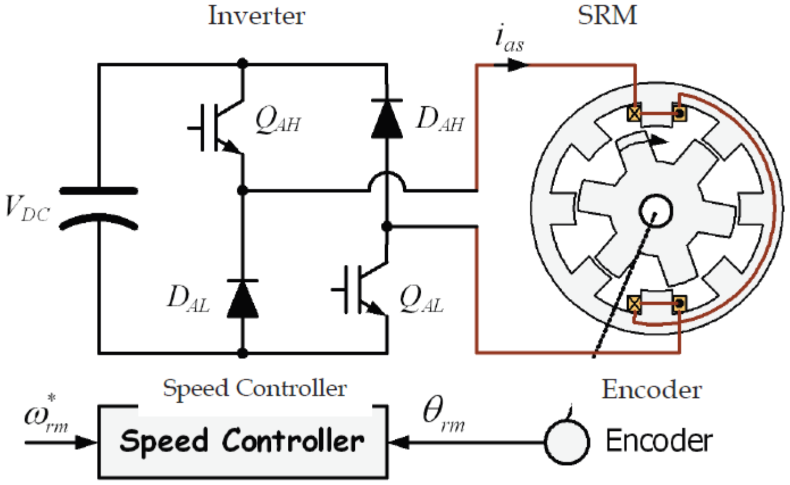

Fig. 1 SRM with One Phase Asymmetric Inverter

The number of poles on the SRM's stator is usually unequal to the number of the rotor to avoid the possibility of the rotor being in a state where it cannot produce initial torque, which occurs when all the rotor poles are aligned with the stator poles. Fig.1 shows a 8/6 SRM with one phase asymmetric inverter. This 4-phase SRM has 8 stator and 6 rotor poles, each phase comprises two coils wound on opposite poles and connected in series or parallel consisting of a number of electrically separated circuit or phases. These phase windings can be excited separately or together depending on the control scheme or converter. Due to the simple motor construction, an SRM requires a simple converter and it is simple to control.

Proposed two-stage converter can be seen in Fig. 1. 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). Phase winding energizing is done by machine side converter as second stage [6, 7]. 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.

The reference current vector can be realized by using the two limiting active vectors of the sector. The resulting output line-voltage space vector defined by:

$$\overline{V}_{OL} = v_{AB}(t) + \overline{a} \cdot v_{BC}(t) + \overline{a}^2 \cdot v_{CA}(t) \tag{3.1}$$

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

$$\begin{aligned} d_\mu &= {}^{T_\mu}\!/_{T_S} = m_c \cdot \sin(60^\circ - \theta_{sc}), \\ d_\upsilon &= {}^{T_\upsilon}\!/_{T_S} = m_c \cdot \sin(\theta_{sc}), \\ d_{0c} &= {}^{T_{0c}}\!/_{T_S} = 1 - d_\mu - d_\upsilon \end{aligned} \tag{3.2}$$

Where mc is the modulation index, TS is the sampling interval and sc θ is the angle between the reference vector and the first active vector [8].

III. SIMULATION DIAGRAM AND RESULTS

The performance of the proposed method is demonstrated in simulation and experimentally using a 4-KW SRM drive that a dc machine is mechanically coupled to it. The experimental setup is based on fixed- point TMS320F2812 board as a suitable choice for implementing motor controllers applications and executing the control algorithm. The current control is implemented by a closed-loop control with hysteresis switching control of the converter. The SRM rotor position is obtained from an optical encoder which is installed on the rotor shaft. The SRM drive system is conducted on a partial load. The current reference is 3 (A).

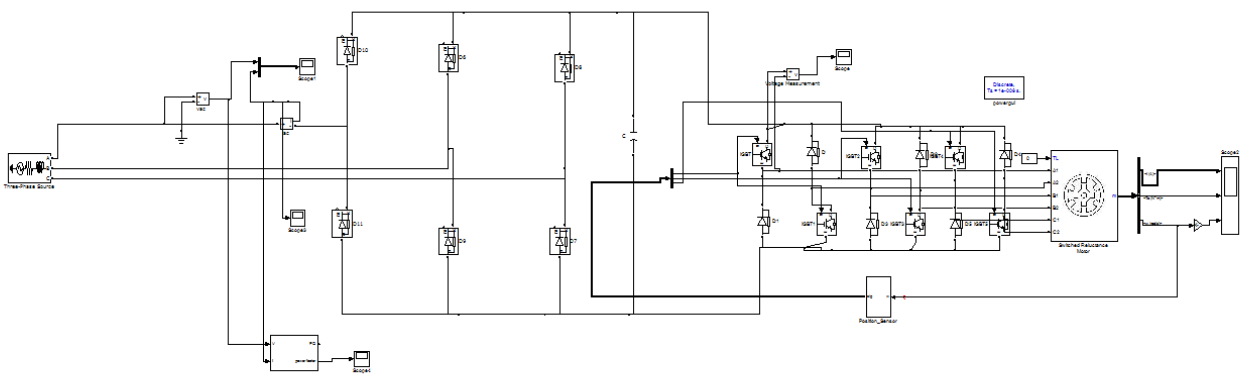

Fig 2: Simulation DIAGRAM for SRM BASED DRIVE

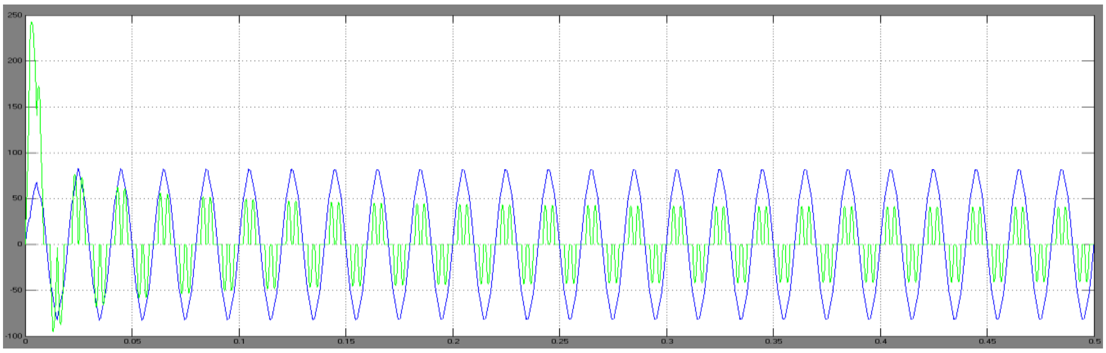

Fig 3: Simulation Result for Input Voltage and Current

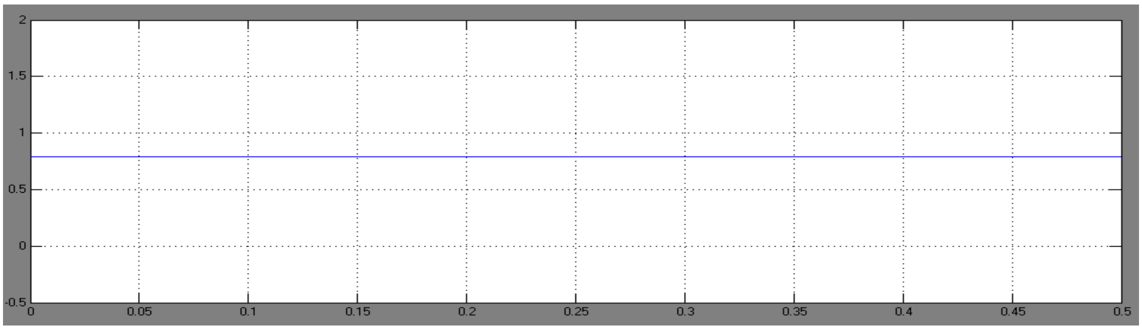

Fig 4: Simulation Waveform for Power Factor

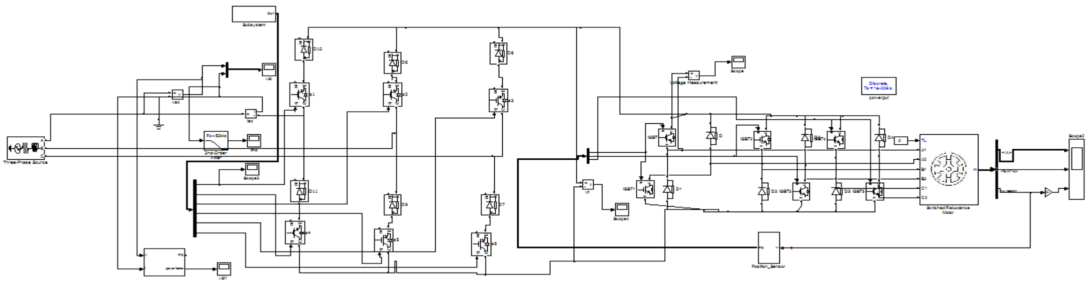

Fig 5: Simulation Diagram for Proposed Converter

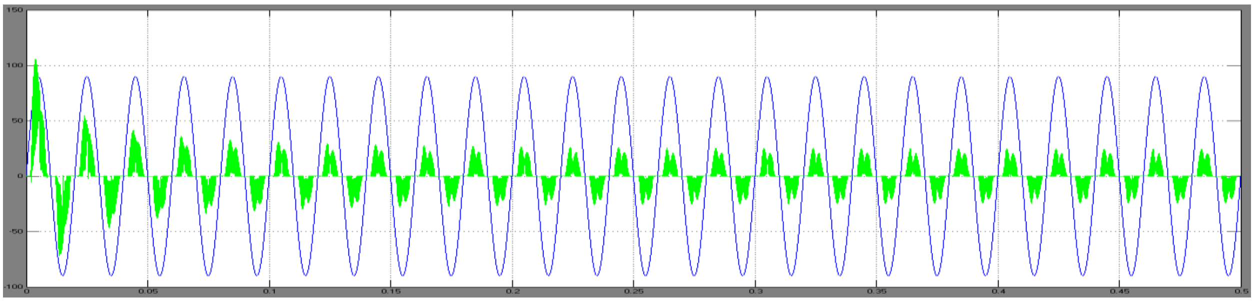

Fig 5: Simulation Result for Input Voltage and Current for Proposed System

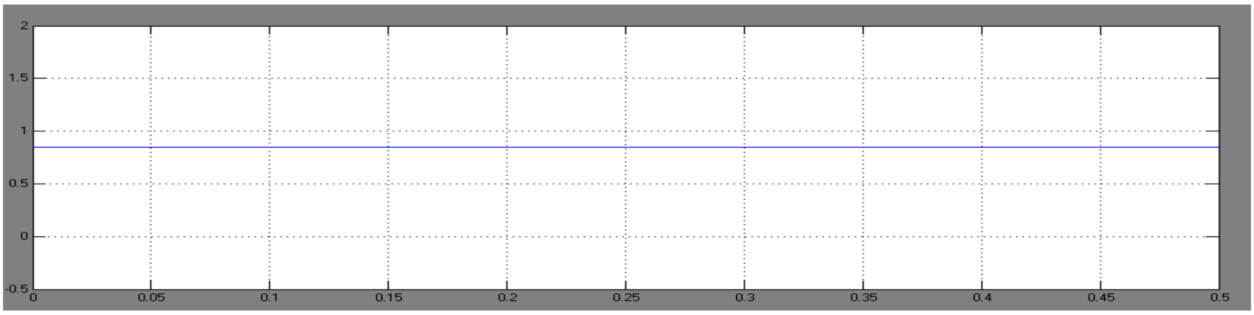

Fig 5: Simulation Waveform for Power Factor for Proposed Converter

IV. CONCLUSIONS

A current source rectifier (CSR) based converter is established to modify the input current of the drive, improving the power factor of SRM drive. Dc link's capacitors eliminating and as a result creating 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 DSP-equipped SRM. The simulation and experimental results demonstrate the desired condition.

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