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New Converter for SRM Drive With Power Factor Correction

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Abstract:

The SRM has become an attractive candidate for variable speed drives applications and is rapidly advancing due to the advent of inexpensive, high power switching devices and since possesses many distinguished merits, such as simple construction while the rotors have no windings or magnets, negligible mutual coupling, higher or comparable reliability due to fault tolerant robust structure and low cost.

When SRM is operated as generator (SRG), it's widely used in aeronautical industries and primely as wind generator in wind based energy generating system.

In this paper various converter topologies of the switched reluctance motor drive has been studied. A comparison between the various converter topologies has been done on the basis of Phase current waveform, Fourier analysis and total harmonic distortion.

After the work of comparing all the converters for the SRM it is observed that the component sharing converter gives best performance. As a extension to this work Power Factor correction is also considered in the work.

As SRM is a DC drive we need DC supply and Rectifier is used to get DC output from AC input, In this work we are improving Power factor at Input side.

Keywords:

Switched Reluctance motor (SRM);PI Controller; Power factor correction(PFC); Total harmonic distortion(THD);

I.INTRODUCTION:

The switched reluctance motors (SRMs) have a simple and robust structure with low inertia and direct drive capability, thus SRM drives are applicable to many industrial fields. However, the converter configuration of SRM drive is not standard. Numerous converters for SRM drives were proposed, developed and used in industrial applications [1].The main considerations in the design of a single-switch-per-phase converter for a switched reluctance motor drive with particular attention to the choice of converter topology, the type of switching devices, the normalized rating of the power devices, and input filter design [2].

A typical switched reluctance motor drive essentially consists of four basic components: Power Converter, Control Logic Circuit, Position Sensor and Switched Reluctance Motor. The phase windings of a doubly salient switched reluctance motor are fed with unipolar pulses of current from a suitable power converter to control the speed and torque of the motor [4].

The essential features of the power switching circuit for each phase of the switched reluctance motor comprises of two parts: A controlled switch to connect the voltage source to the coil windings in order to build up the current, when the switch is turned off there should be an alternative path for the current to flow, since the trapped energy in the phase winding can be used for the other strokes. In addition to this, it protects the switch from the high current produced by the energy trapped in the phase winding [8]. SRM has become an important alternative in various applications both within the industrial and domestic markets, namely as a motor showing good mechanical reliability, high torque-volume ratio and high efficiency, plus low cost.

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As a generator SRM find its application in the aeronautical industries and in integrated applications primely as wind generator in wind based energy generating system. In this paper the various topologies viz. resonant, bifilar, split dc supply, R-dump, asymmetric bridge Converter with respect to voltage rating, number of switches per phase, THD and applications are compared. The phase current response with respect to time and frequency are also compared. Among these converters, it's observed that the asymmetric bridge converter is the most popular and best performed one.

In this paper, a new and cost effective converter topology, which is the modified asymmetric bridge topology, is developed. It inherits the advantages of the asymmetric bridge topology. Furthermore, it has higher utilization of switch devices. Thus, the proposed converter circuit can be designed with more compact configuration, smaller size and lower cost.The attractive features of component sharing converter less number of switches and improve power factor. This converter is modified asymmetric bridge converter. New converter is less cost compact size.The various topologies viz. resonant, bifilar, split dc supply, R-dump, asymmetric bridge converter performance were analyzed the variation of phase current with respect to time and frequency for converters are compared and inference.

Each converter with respect to voltage rating, number of switches per phase, THD and applications less number of switches in component sharing converter less switching losses improves power factor correction. Though it has disadvantage of using more number of switches this topology provides independent phase control, no shoot through fault and it is most suitable for high speed applications.

II.PROPOSED SYSTEM

A. Component sharing converter topology

Fig 1 illustrates the component sharing converter circuit for four phase SRM drive. It can be observed that the component sharing converter needs eight IGBT modules and four diodes, in comparison to eight IGBT modules and eight diodes in asymmetric bridge converters. On the other hand, each phase is controlled by different switching devices. It is helpful to reduce the temperature rise and extend the lifetime of IGBT components.

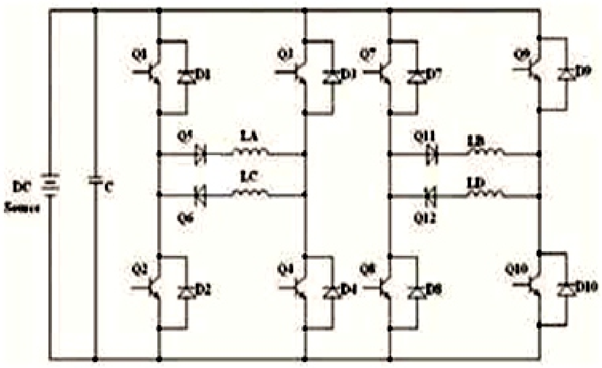

Fig. 1. Component sharing converter topology for four-phase SRM drives

According to the principle of operation of SRM drives, the energy conversion process may occur simultaneously in two adjacent phases, in order to acquire high starting torque and low torque ripple. This mode of operation may cause a current overlap [1].

In the developed converter, therefore, alternate phases are grouped together, such as Phase A and Phase C, or Phase B and Phase D, shown in Fig 1. This allows independent current control of each phase with overlapping currents not exceeding one phase cycle duration.

Though it has disadvantage of using more number of switches this topology provides independent phase control, no shoot through fault and it is most suitable for high speed applications.

The results are beneficial in that the system acoustics and efficiency are improved with no added space requirements. The improvement in efficiency is particularly relevant to large drives. The decrease in toque ripple, which is normally high in SRM drives, reduces the acoustical noise generated.

B. Operation of component sharing converter

For the developed converter, the operation of each phase includes three modes; they are charging, freewheeling and discharging. For the sake of simplicity of the illustration, the operation of two phases in a group is analyzed in the following discussion. Fig 2, Fig 3 and Fig 4 depict the operations of phase A and Phase C in a group, respectively.

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Mode 1: Charging

Referring to Fig 2, if the switching devices Q1, Q 4 and diode Q5 are turned on, the DC link voltage is then applied to Phase A and the current rises rapidly in the phase winding. In the same way, if the switching devices Q2, Q3 and diode Q 6 are switched on, Phase C is charged through the switches Q2, Q3 and diode Q6.

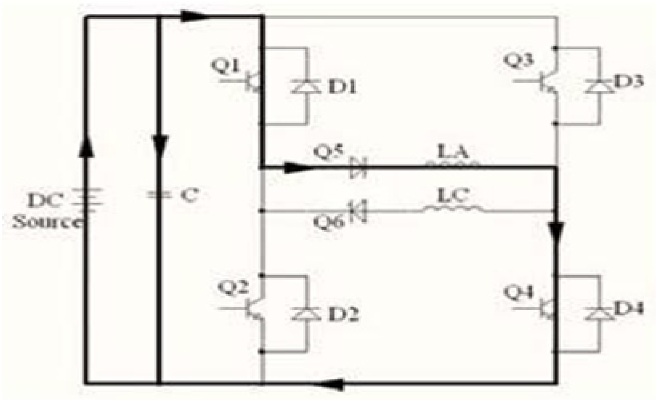

Fig. 2. Charging Operation of phase-A

Mode 2: Freewheeling

It can be seen from Fig 3, if the switch Q1 is turned off and the switch Q4 and diode Q5 are still on, then current circulate though the switch Q4, and forward -biased diodes Q5, D2.

In this mode there is no energy transfer between phase winding and DC source. Similarly, Phase C freewheels through switch Q2 and the diode Q6, D4 when the switch Q3 is turned off and the switch Q2 and diode Q6 are still on.

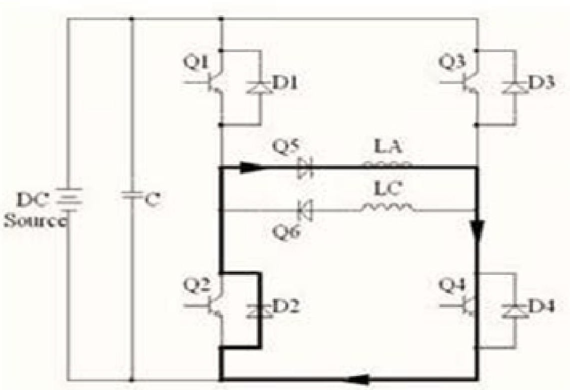

Fig. 3. Freewheeling Operation of phase-A

Mode 3: Discharging:

As is shown in Fig 4, the switches Q1 and Q4 are turned off and Q5 is still forward biased in this mode. Consequently, Phase A discharges to the DC link capacitor, through D2, D3 and Q5. In the same way, Phase C discharges to the DC link capacitor through Q6 and the diodes D1 and D 4 if the switches Q2 and Q3 are switched off and diode Q6 is still on.

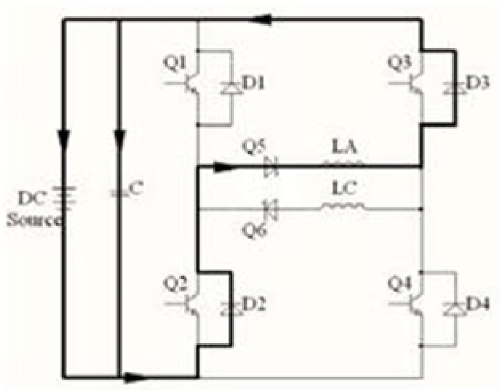

Fig. 4. Discharging Operation of phase-A

4. Equivalent Circuit:

Fig 5 illustrates the equivalent circuit for one phase of the SRM

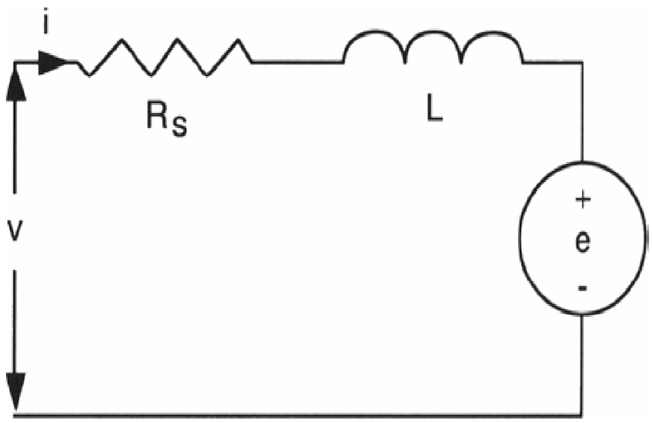

Fig.5. Single phase equivalent circuit of SRM

The operation of the Switched Reluctance Motor is described by the voltage and torque equation of each phase. For convenience, let us write as . The voltage drop on the phase resistance R can be neglected as it is much less than the induced voltage. Assuming magnetic linearity, the phase voltage will be

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$$v_q = L_q \frac{\partial i_q}{\partial t} + i_q \frac{\partial L_q}{\partial t} \quad (1)$$

The above equation may be rewritten as

$$v_q = L_q \frac{\partial i_q}{\partial t} + \frac{i_q}{2}\frac{\partial L_q}{\partial t} + \frac{i_q}{2}\frac{\partial L_q}{\partial t} \quad (2)$$

The expression for the instantaneous power will be obtained by multiplying either side equation (2.12) with and is given as

$$v_q * i_q = \left(L_q \frac{\partial i_q}{\partial t} + \frac{i_q}{2}\frac{\partial L_q}{\partial t} + \frac{i_q}{2}\frac{\partial L_q}{\partial t} \right) * i_q$$

$$v_q * i_q = \left[L_q i_q \frac{\partial i_q}{\partial t} + \frac{i_q^2}{2}\frac{\partial L_q}{\partial t} \right] + \frac{i_q^2}{2}\frac{\partial L_q}{\partial \theta}\frac{\partial \theta}{\partial t} \quad (3)$$

The term in brackets may be rewritten as $\frac{\partial}{\partial t}\left(\frac{1}{2} L_q i_q^2\right)$ and the term $\frac{\partial \theta}{\partial t}$ is the motor speed and thus

$$v_q * i_q = \frac{\partial}{\partial t}\left(\frac{1}{2} L_q i_q^2\right) + \frac{i_q^2}{2}\frac{\partial L_q}{\partial \theta}\omega \quad (4)$$

The term $\frac{1}{2} L_q i_q^2$ is recognized as the increase in stored magnetic energy and the term $\frac{i_q^2}{2}\frac{\partial L_q}{\partial \theta}\omega$ as the power converted to mechanical work. But, the mechanical power developed per phase is

$$W_q = T_q * \omega (5)$$

where T_q is the torque developed per phase. Equating equation (5) with the second term in equation (4) we get

$$T_q = \frac{1}{2}\frac{\partial L_q}{\partial \theta} i_q^2 \quad (6)$$

Equation (2) shows that the instantaneous torque per phase, even with the simplifying assumptions, is a quadratic function of the phase current and is determined by the current injected into the phase winding and is positive in the rotor position interval at which the phase inductance is increasing as the rotor position θ increases.

This torque is negative when the phase inductance is decreasing as θ is increases and it is zero where the phase inductance is constant. Substituting equation (7) into equation (6) yields the instantaneous torque developed by phase A over the four sectors in Fig 2.4 respectively as

$$T_A(\theta) = \begin{cases} 0 & -\theta_1 \le \theta \le 0 \\ \frac{1}{2}Ki^2 & 0 \le \theta \le \beta_s \\ 0 & \beta_s \le \theta \le \beta_r \\ -\frac{1}{2}Ki^2 & \beta_r \le \theta \le \beta_r + \beta_s = \alpha_r - \theta_1 \end{cases} \quad (7)$$

where K is given by equation (2). The instantaneous torque developed by the motor is the sum of the instantaneous toques developed by the individual phases, i .e

$$T = \sum_{q=1}^{m} T_q = \frac{1}{2}\sum_{q=1}^{m} \frac{\partial L_q(\theta)}{\partial \theta} i_q^2 \quad (8)$$

For the switched reluctance motor rotating in the positive direction, a motoring torque is therefore developed when the rotor travels along the zone of increasing inductance $\frac{\partial L}{\partial \theta} > 0$. No torque is developed when the rotor travels along the unaligned or the aligned zones $\frac{\partial L}{\partial \theta} = 0$.

A braking torque is developed when the rotor travels along the zone of decreasing inductance $\frac{\partial L}{\partial \theta} < 0$.

IV.SRM DRIVE USING COMPONENT SHARING CONVERTER:

In order to observe the performance of component sharing converter for SRM drives, the simulation based on MATLAB/SIMULINK was carried out. Fig 5 and Fig 6 shows the developed simulation block diagram in MATLAB/SIMULINK. The simulation results for flux, phase current, torque, and speed variation with respect to time are shown in Fig 7.

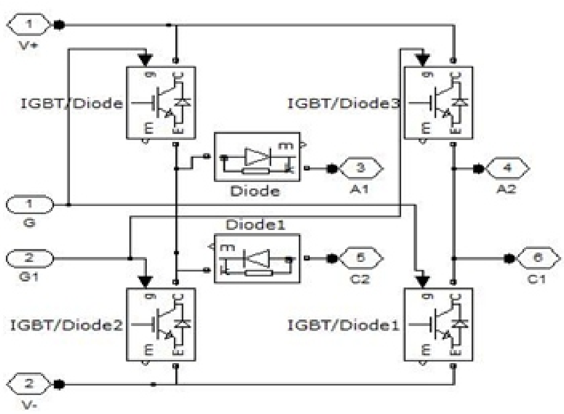

Fig. 6. Converter Circuit.

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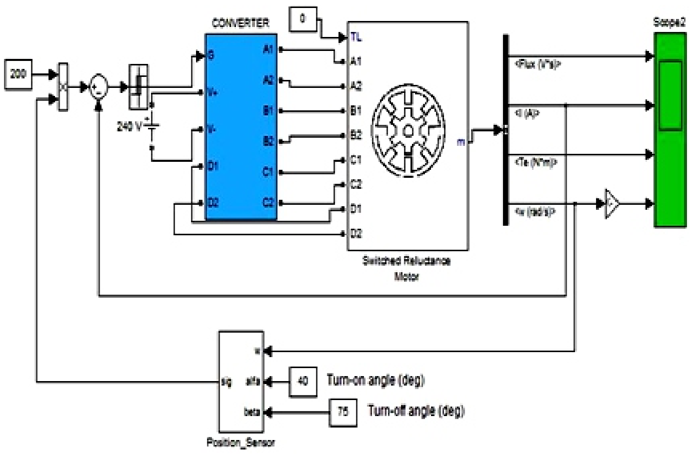

Fig. 7. Block diagram of component sharing converter based SRM drive.

As for Phase A, for example, the phase current rises rapidly when the switches Q1, Q4 and diode Q5 are turned on. Then, the switch Q1 is turned on or off during the hysteresis current control. The switch Q4 and diode Q5 are always turned on during the hysteresis current control to provide the path for freewheeling.

Finally, the switches Q1 and Q4 are switched off when the conduction angle reaches the specified value. The energy stored in Phase A discharges to the DC link capacitor through Q5 and the diodes D2 and D3, and the phase current declines to zero fast. It can be observed that the simulation current waveform demonstrates that the proposed converter for SRM drives can be used to implement the hysteresis current control.

In the same way, the single pulse voltage control and the PWM voltage control are also accomplished in the component sharing converter. From the analysis and simulation, therefore, the salient merits of the proposed converter can be summarized as: (1) It has the higher utilization of switch compared to traditional asymmetric bridge converters; (2) The charging, freewheeling and discharging modes can be accomplished; (3) The single pulse voltage, hysteresis current and PWM voltage controls can be implemented; (4) The converter is capable of the positive, negative and zero voltage output capability. The drawback of this converter is that it requires an even number of machine phases, but nowadays most of the SRM drives are designed to have an even number of machine phases, so this drawback will not restrict its applicability in practice.

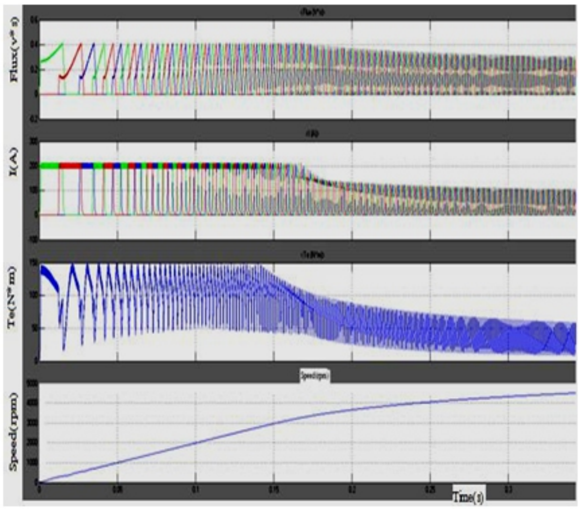

Fig. 8. Component sharing converter for SRM Drive waveforms

VI. MATLAB/SIMULINK RESULTS:

The Simulink diagram of component sharing converter based SRM drive with PFC

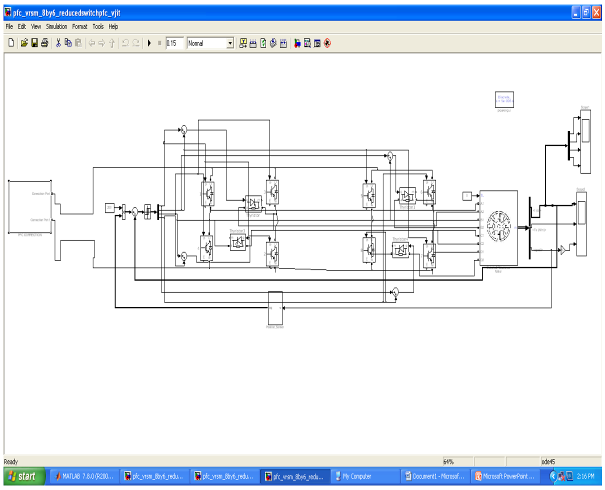

Fig11.The Simulink diagram of component sharing converter based SRM drive with PFC

simulink model of power factor correction

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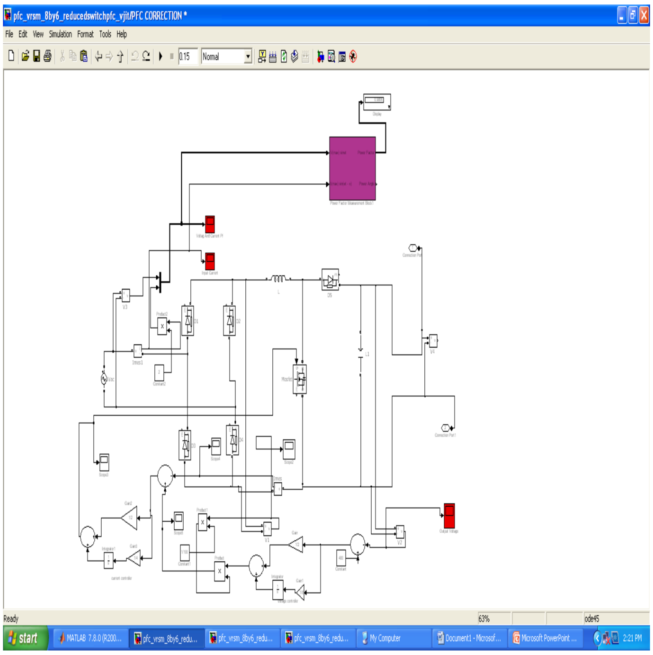

Fig 9.simulink model of power factor correction

Simulation of Power factor measurement block

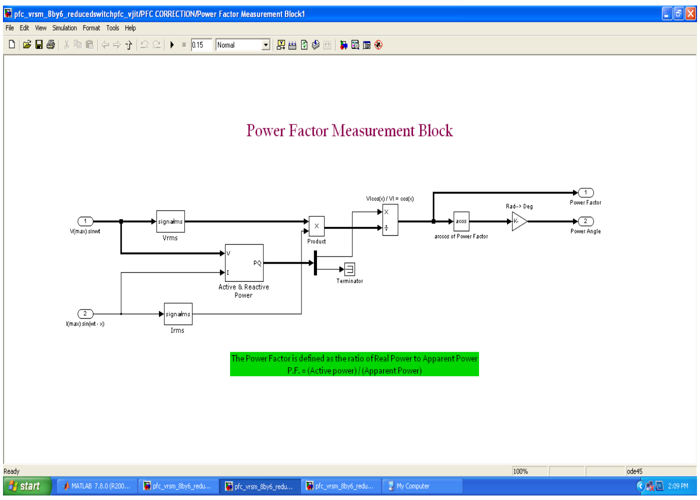

Fig13.Simulation of Power factor measurement block

Power Factor=Real Power /Apperant Power
Simulation model of pfc

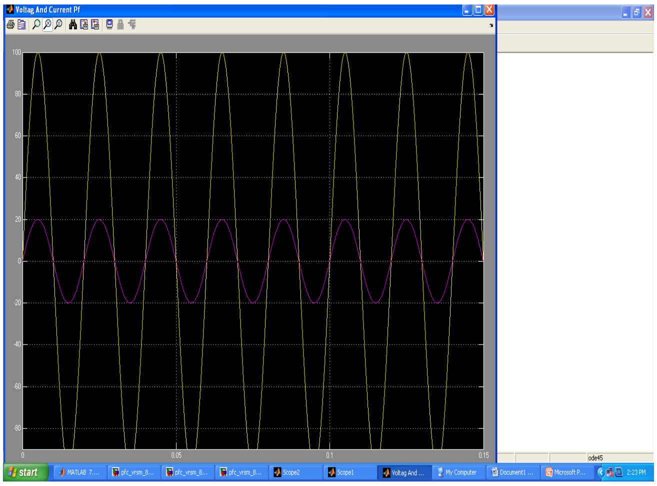

Fig13.Voltage &current wave form

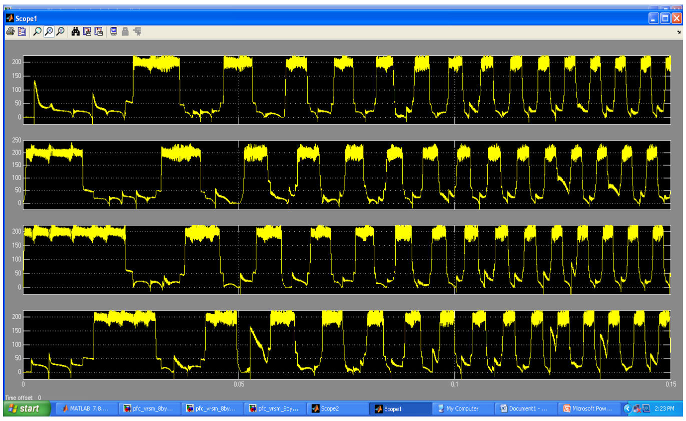

Fig14.Current phases A,B,C,D

CONCLUSION:

In this project, various converter topologies of the switched reluctance motor drive have been studied. A comparison between the various converter topologies has been done on the basis of Phase current waveform, Fourier analysis and total harmonic distortion. Compared to the conventional asymmetric bridge converter with power factor correction, the proposed one using component sharing converter with power factor correction is more compact and has higher utilization of power switches and lower cost, without degradation in performance. The developed converter has three conventional operating modes that are charging, freewheeling and discharging modes. Hence, the single pulse voltage control, the hysteresis current control and the PWM voltage control are implemented in the developed converter.

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