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Fuzzy Controlled Bridgeless Cuk Converter Fed Switched Reluctance Motor

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Abstract: The researchin this study aims at designing and modelling of a bridgeless cuk converter for driving a switched reluctance motor. Bridgeless Cuk converters are new series of AC-DC converters, it contain very less ripple of voltage and current and have output wave with good quality, high power concentration and good transfer voltage gain and no circuit elements parasitic limits of traditional converters. Bridgeless Cuk converters have good voltage transfer gains in arithmetic development on step by step. For the switched reluctance Motor drive, the C-dump converter is used. The present design aims at improving the effectiveness of the switched reluctance motor drive system by the incorporation of the Bridgeless Cuk converter between the electrical source and the drive system. The rule base of the fuzzy logic controller is modified to improve the stability of the controller without affecting the system performance. MATLAB simulation results are presented in this paper to explain the working of the proposed drive.

Key words: Bridgeless CUK converter, SRM, fuzzy logic controller, DC-DC converter, C-dump converter

INTRODUCTION

Switched Reluctance Motors (SRM) have inherent merits such as easy structure with non-winding assembly in rotor side, better tolerance, heftiness, low cost with no permanent magnet in the construction and it can operate with high temperatures or in extreme temperature variations (Ahn *et al*., 2010). It is an electric machine which converts the reluctance torque into mechanical output. In SRM, the stator and rotor enclose a structure of salient-pole, due to salient poles it generate a high output torque. The torque is created by the arrangement inclination of poles (Ahn *et al*., 2010).

Bridgeless Cuk converters allow power transfer in both directions (Kavitha and Uma, 2008). Due to their capability to reverse the direction of flow of power and thereby the current direction of the motor is changed. Power quality issues are the major issue, for reducing the harmonics in supply current by various international power quality standard like the International Electro technical Commission (Bist and Singh, 2014) (IEC) 61000-3-2. In all AC-DC converters, the power transfer efficiency and output voltage are limited by power electronic elements. But in calculation, usual converters can produce high voltage with high efficiency. BL-Cuk converters (Luo and Ye, 2013) are new AC-DC converters that defeat the above disadvantages effects and for the increasing of voltage and the power transfer efficiency. These converters produce improved voltage from low voltage of photovoltaic operation.

However, fundamental converters like as Boost converter and Buck converter cannot be use in the high-power circumstances and at the similar time have many limitations. In modern years, conversion methods have been improved rapidly and there are stacks of topologies of DC-DC converters. Bridgeless converters are more suitable in order to improve the power factor at Source of supply. The distinctive characteristic of a bridgeless PFC converter is which eliminates the need of a diode bridge rectifier at the input. Which reduce the power losses, so we get improves overall system efficiency as a result with equal cost savings. PFC rectifiers are used to recover the rectifier power density and to decrease noise emissions via soft switching methods or coupled magnetic techniques (Yang, 2012; Agirman *et al*., 2001).

A usual PFC scheme has lower efficiency due to major losses in the diode bridge. Usually boost converters are used as front end rectifiers (Barnes and Pollock, 1998; Lee *et al*., 2007). For low level voltage applications like computer industry or telecommunication an isolation transformer or extra converter is needed to step down the voltage level. Bridgeless PFC buck converters are restricted for step down applications (Tseng *et al*., 2000). Input line current cannot trace the input voltage around zero crossings of the input line voltage.

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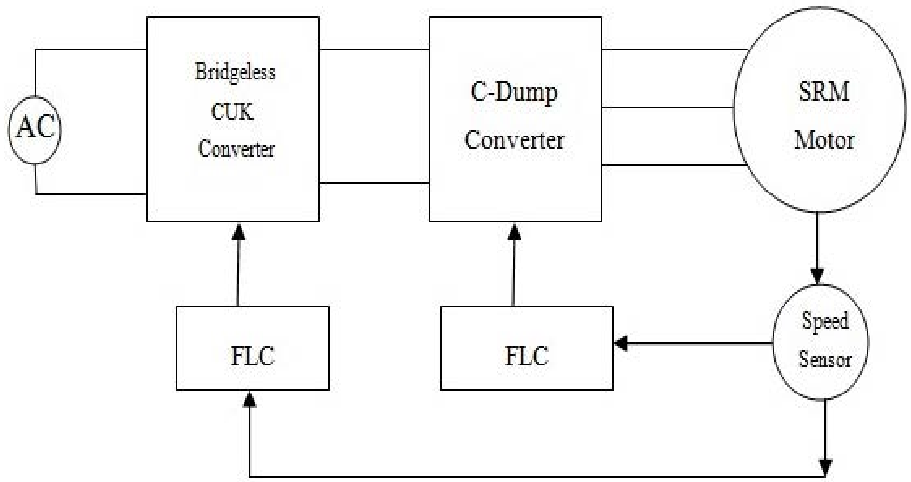

Fig. 1: CUK converter based SRM drive

SRM drive requires the power converters to control the switching sequence of the stator windings (Agirman *et al*., 2001). An asymmetric bridge SRM converter has 2 switches (plus 2 diodes) per phase. This type of converter topology gives more flexible and effective control to current waveforms of an SRM but it contains large number of switches (Barnes and Pollock, 1998). The c-dump circuit has only one switch per phase (Lee *et al*., 2007). Stator winding is transferring the stored magnetic energy after it turn-off the power switch, to the storage capacitor and it sent to the power supply through a step-down dc chopper. The technique could limit the overall cost of the SRM drive.

The self-tuning fuzzy logic controller is used to adjust the output scaling factor with their current states of the controller (Mudi and Pal, 1999). The membership functions and scaling factors are tuned for their corresponding working operation is said to be self-tuning fuzzy logic controller (Chung *et al*., 1998).

Proposed CUK converter fed switched reluctance motor drive: In the proposed circuit model given input AC supply is converted into the dc supply with the help of the BL-CUK. The CUK converter is used to improve the output quality of the supply. It means in the CUK converter output it contain the low level harmonics, small distortion and less ripple. By controlling the CUK converter output, SRM motor output performance is improved. The CUK converter operation and SRM Drive operation is controlled by using Fuzzy Logic Controller (FLC). Thus the C- Dump converter (Lee *et al*., 2013) is the more efficient converter compare to another converter.

Thus, the C- Dump converter is use to drive the SRM motor. The FLC is used to give the rotor position and also it produces the pulse signal to the C-dump converter. The features of FLC are five fuzzy sets for input and output, triangular membership function, mamdani fuzzy inference system with implication by min operator and defuzzification using centroid method. The switching of the Cuk converter switches are controlled by FLC thereby controlling the SRM drive ripples in torque and current (Fig.1).

MATERIALS AND METHODS

Operating principle of BL-Cuk converter: Cuk converter is actually combination of a boost converter and a buck converter. Cuk converter has the following merits. Such as continuous output current, continuous input current, output voltage can be either improved or fewer than the input voltage.

The bridgeless Cuk converter working in a DICM mode which gives an inherent PFC and require a easy voltage follower method for the voltage control and small size of heat sink for the switches (Luo and Ye, 2003, 2004; Silpa and Chitra, 2014).

Operation of bridgeless Cuk converters: The mode of operation of a PFC converter is a crucial problem because it affects the cost and rating of the components used in the PFC converter. Discontinuous Conduction Mode (DCM) and Continuous Conduction Mode (CCM) are broadly used in practical application. In DCM or CCM, the current of the inductor or the voltage across in-between capacitor in a PFC converter remains discontinuous or

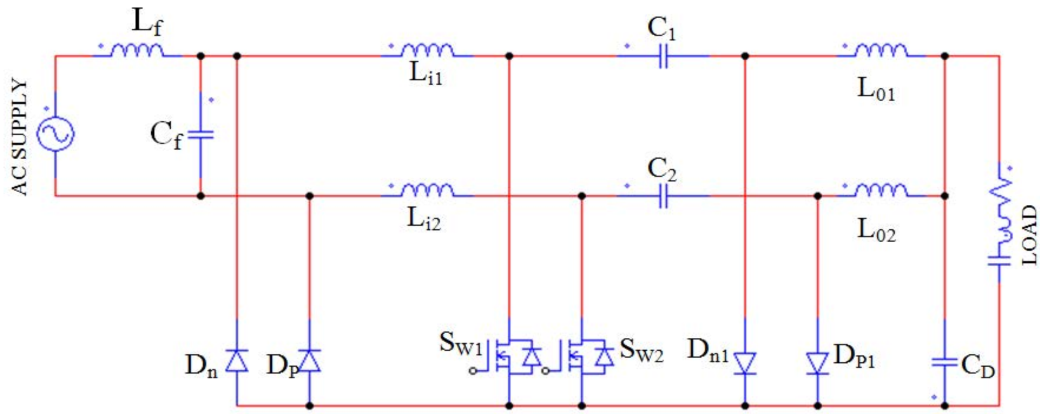

Fig. 2: Bridgeless Cuk converter

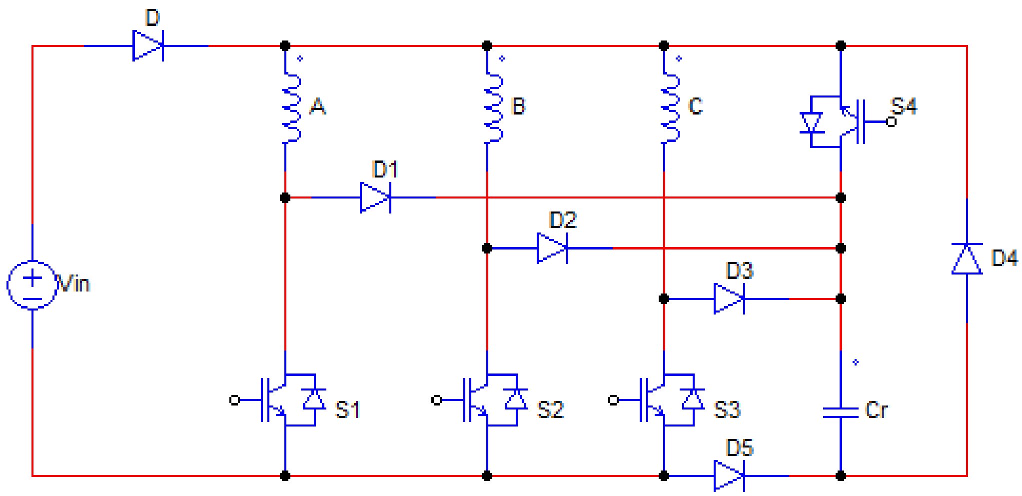

Fig. 3: C-dump converter

continuous in a switching period correspondingly. To activate a PFC converter in CCM, it requires three sensors (2 voltage, current) while a DCM process achieved by using only one voltage sensor. While the PFC converter operates in DCM mode the stresses is high, when compared to CCM mode operation. By operating the converter in DCM, many merits can be achieved such as near to unity power factor, at zero current the power switches are turned ON and output diodes are turned OFF (Fig. 2).

Operation of converter is depending upon the application. For high power applications CCM is suitable and low power application DCM is preferred. Conversely, DCM operation considerably increases the conduction losses due to the large current stress through circuit apparatus. DCM leads to one limitation, it can operate at low-power applications only (>300 W). So the DCM is chosen for low-power applications.

C- Dump converter for SRM drive: It is derived from the C-dump converter (Lee *et al*., 2007) circuit by eliminating the inductor of the Cuk converter. The energy can be stored in the capacitor and it is used for the next phase and being returned to the dc supply of conventional C-dump representation. At that time the capacitor have the voltage level of 2 V_{dc} in C-dump converter, its proper utilization significantly improves the drive performance.

By the modified C-dump converter, the energy in the dump capacitor is directly utilized to energize phase windings and to maintain the dump capacitor voltage at V_{dc} rather than $2V_{dc}$. Control of the dump capacitor voltage is streamlined and replication of the phase currents is enabled in an energy efficient C-dump converter. Figure 3 shows the energy competent C-dump converter topology, derived from the conventional C-dump converter (Tseng *et al*., 2000). The topology could minimize the whole cost of the switched reluctance motor drive. The potential ratings of the c-dump capacitor and a few of the switching devices in the energy efficient C-dump converter are reduced to the supply voltage (V_{dc}) level likened to twice the supply voltage ($2V_{dc}$) in the conventional C-dump converter. In addition, the converter has modest control requirements and allows the motor phase current to freewheel during chopping mode.

The A phase starts to magnetize together S1 and S4 on. The phase is energized from the capacitor that is transfer to the main source until the capacitor voltage drops to the level of supply voltage. At that time the blocking diode becomes forward biased and the source begins to provide for energy to the phase. The current is maintained at the charge level by switch S1 on and off. The phase current freewheels throughout diode D1 and S4 when S1 is "off". The current commutates from S1 and S4 "off" and charges the dump capacitor. Diode D5 stop the demagnetizing current which flowed throughout the source. While A phase is being demagnetized, B phase can be magnetized by turn on S2. During this period, the current through B phase is maintained at the command value by dumping any extra energy into the capacitor. These can be continued for the next phase also.

RESULTS AND DISCSUSSION

Without Cuk converter fed SRM drive: Figure 4 shows the without cuk converter outputs for flux and current. In the results torque range of the motor is reduced and the speed range is also low. Figure 5 shows the without Cuk onverter outputs for torque and speed. The ripple in the motor flux is high and also the current range of the motor is low. Without Cuk converter circuit the motor takes 0.2 sec to reach the steady state condition.

UK converter fED SRM drive: Figure 6 shows the With cuk converter outputs for flux and current. In the results torque range of the motor is increased and the speed range also high. The ripple in the motor flux is low and the current range of the motor is increased. Figure 7 shows the with cuk converter outputs for torque and speed.

With CUK converter circuit the motor takes 0.12 sec to reach the steady state condition when compared to the without CUK converter operation. The acceleration in the torque is high. In the given Simulation results the output torque ripple is reduced when compared to the without CUK converter circuit.

Figure 8 shows the output waveform of the speed for switched reluctance motor using PI controller. From the waveform it shows the desired output speed is attained after 0.22 sec with the set point speed of 2000 rpm. Figure 9 Shows the switched reluctance motor using fuzzy logic controller speed output waveform. From the graphical representation it shows that desired output speed is attained before 0.09 sec with the set point speed of 2000 rpm.

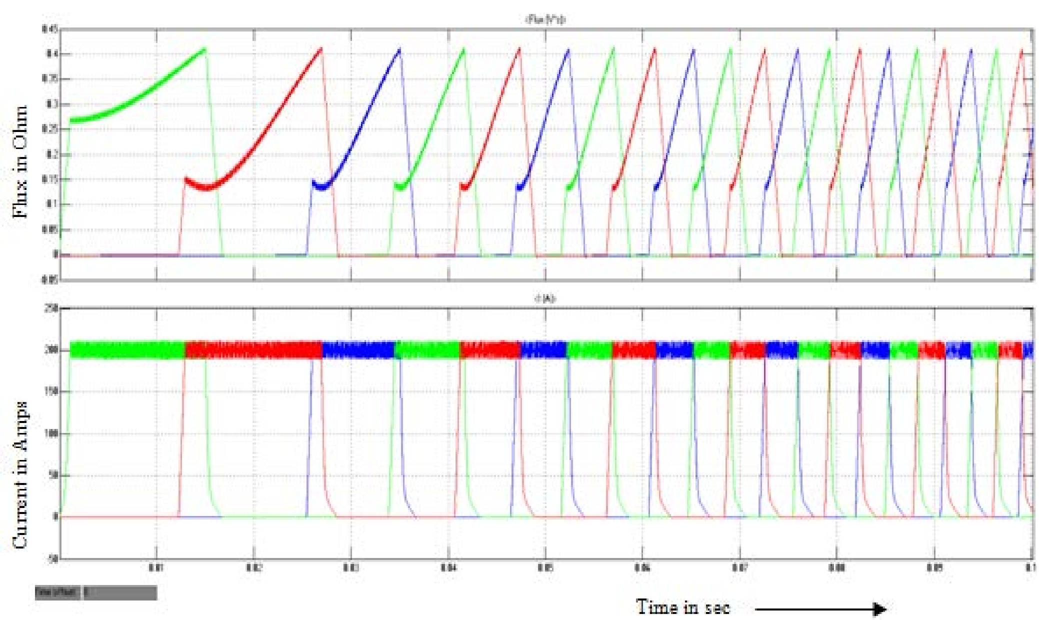

Fig. 4: Without Cuk converter outputs for flux and current

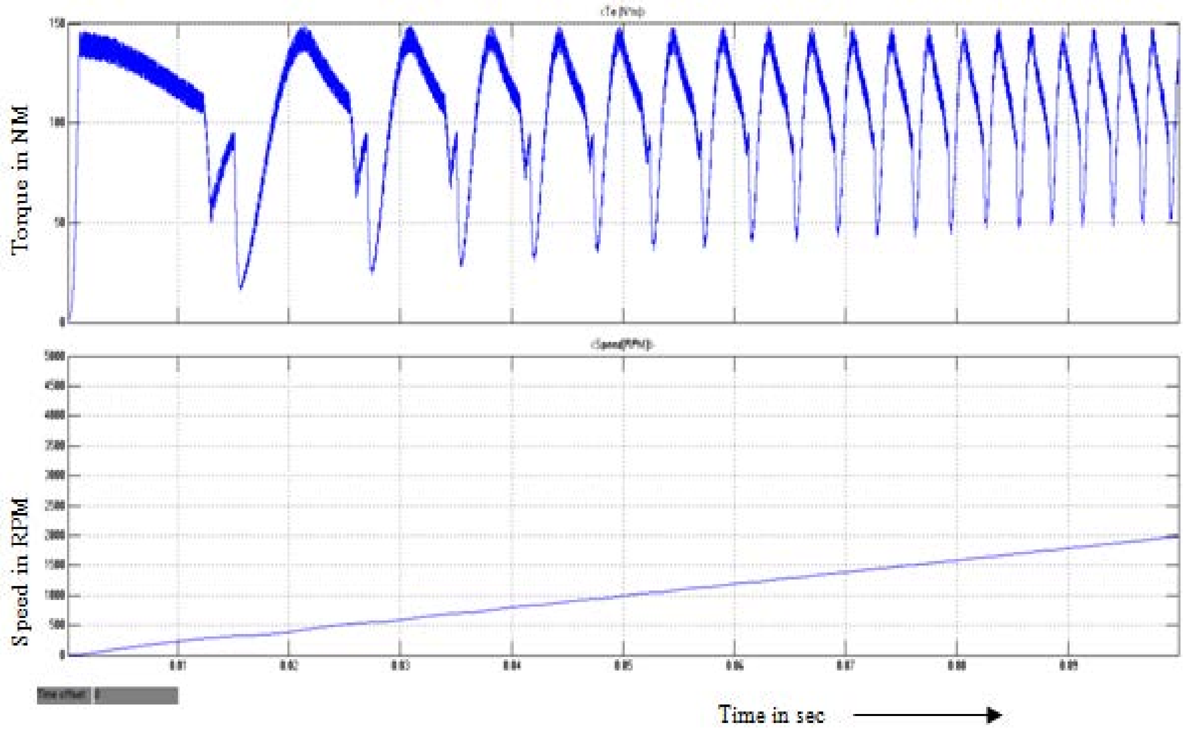

Fig. 5: Without CUK converter outputs for torque and speed

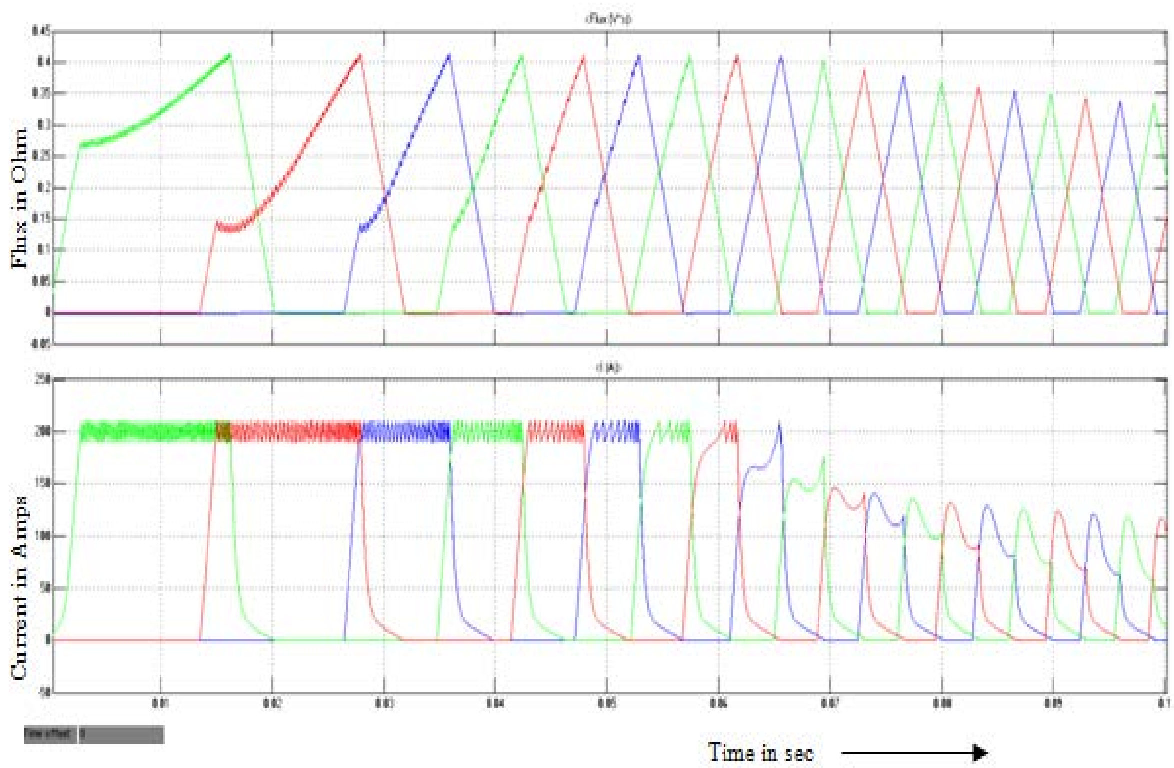

Fig. 6: With Cuk converter outputs for flux and current

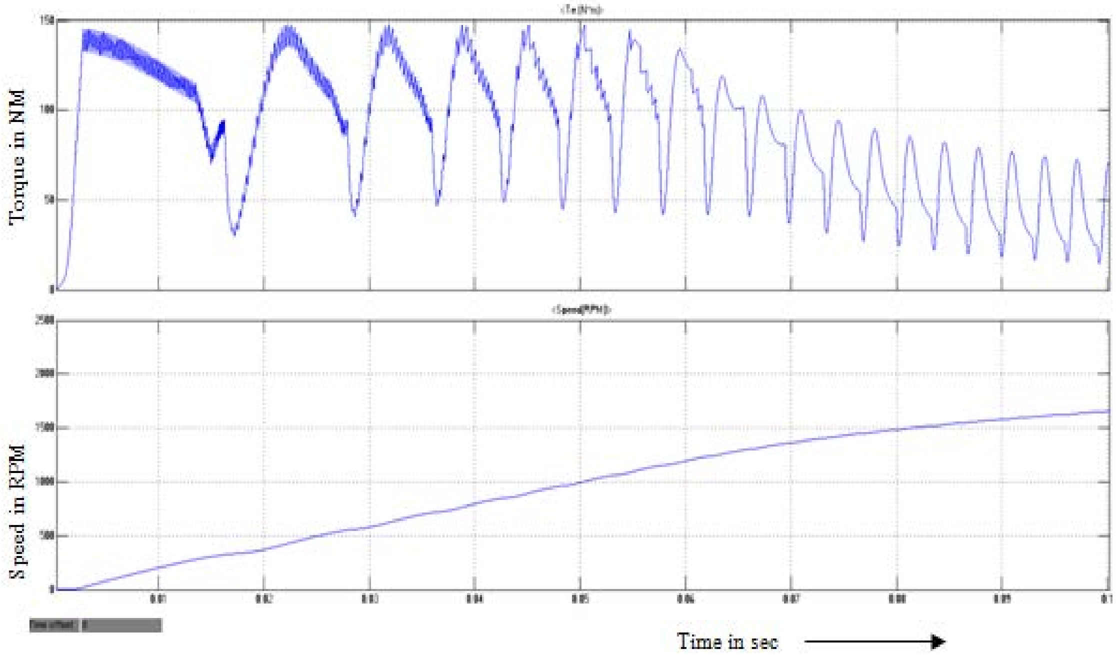

Fig. 7: With CUK converter outputs for torque and speed

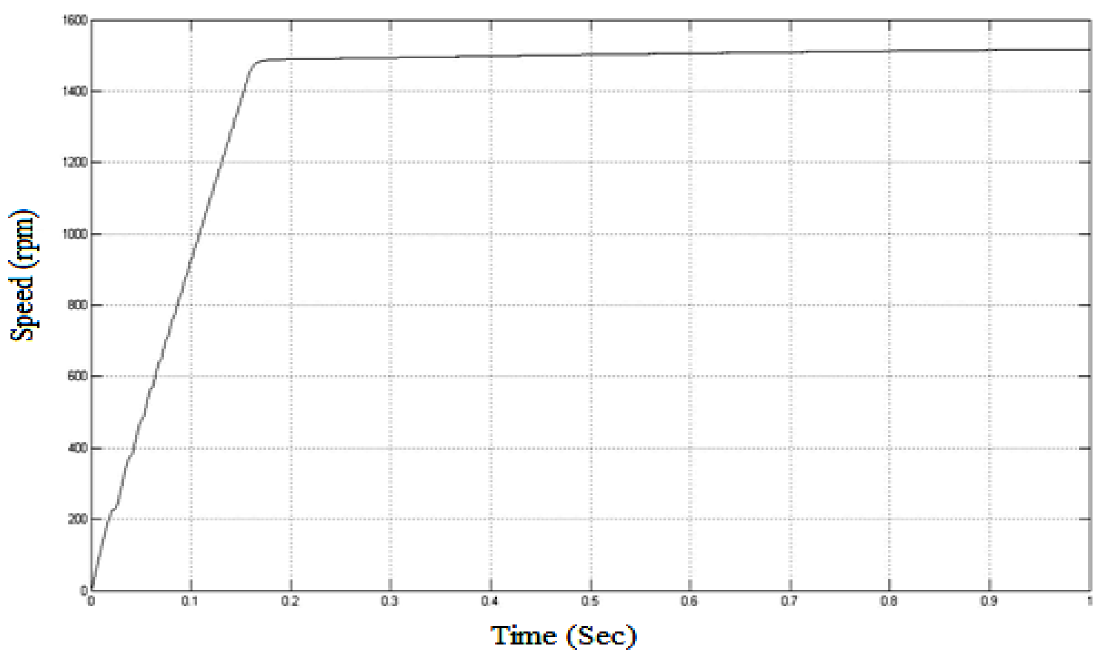

Fig. 8: SRM PI controller speed output waveform

Table 1 shows the various set speed and settling time in PI controller and fuzzy logic speed controller. From the tabulation it shows, the settling time of fuzzy logic controller as low compared to PI controller.

Table 1: Comparative study of set speed and settling time

Speed (RPM)	PI (Settling time)	Fuzzy controller (Settling time)
1500	0.16	0.05
2000	0.22	0.09
2500	0.26	0.12
3000	0.32	0.15

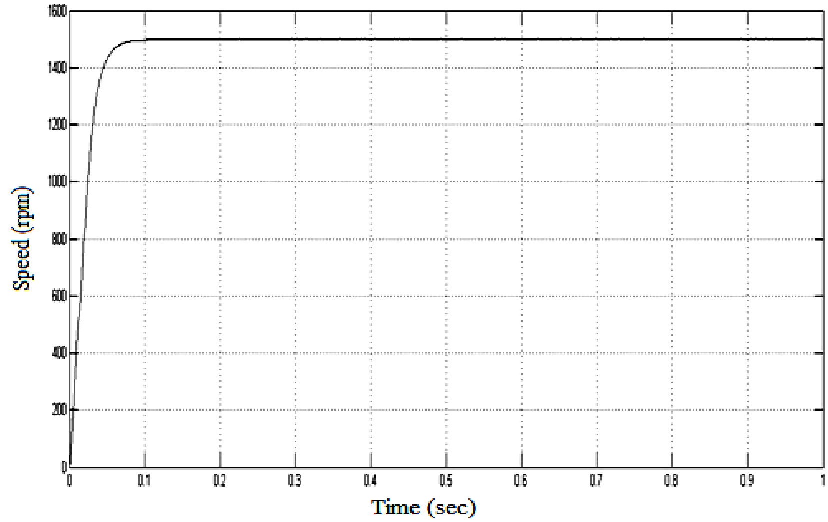

Fig. 9: SRM FLC speed output waveform

CONCLUSION

In this study, a Cuk converter fed Switched Reluctance drive has been introduced. The proposed drive provides increased drive efficiency when compared to the drive without Cuk converter. Here, for the Cuk converter normal PWM pulse generator is used. In future for the Cuk converter operation SVPWM, NEURAL or GENETIC algorithm methods will be implemented for improving the performance of Cuk converter with SRM drive and also for the switched reluctance drive the space vector modulation technique may be implemented. Due to the implementation of Cuk converter the speed of the motor is increased and the torque ripple also reduced. Bridge Cuk converter has to be replaced with Bridgeless Cuk converter so that the power factor is improved when compared to the conventional converters.

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