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Performance Comparison of Cuk and M-Cuk Converter on SRM Drive System

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Abstract: Power factor correction is a method to increase the power factor of the supply and in turn improve the overall power quality of the ac mains supply. Here the control of Switched Reluctance Motor is developed with a power factor correction converter. It utilizes two modified Cuk converter fed Switched Reluctance Motor (SRM) drive to improve the power quality. Cuk converters operates separately for two half cycles of supply voltage. Converter is made to operate in discontinuous conduction mode. The power factor correction converter provides a regulated dc input which in turn is used to control the speed of motor. The design is based mostly for low voltage household applications. Comparative performance analysis is done based on MATLAB results.

Keywords: Power Factor Correction (PFC), Switched Reluctance Motor (SRM), Modified-CUK (M-CUK), Diode Bridge Rectifier (DBR).

I. INTRODUCTION

Power Factor Correction (PFC) converters are popular due to their prominent features of low input current THD (Total Harmonic Distortion) with a high power factor and their input current shaping nature. THD is controlled with the help of circuits consisting of both active and passive filters. There are numerous advantages to be gained with the use of power factor correction.

The requirement of variable speed drive for household applications has increased the interest of manufacturers towards the low cost and highly efficient brushless motor drive. The brushless motors with permanent magnets, are becoming popular due to their high efficiency, however, the cost and availability of the rare earth permanent magnet material, are the limitations associated with these permanent magnet motors [1]. The motor is driven by some sequence of current pulses applied at each phase, that needs control electronics for operation.

The SR motor works on the principle that the magnetic circuit tries to minimize the reluctance (air gap distance) of the magnetic circuit. The magnetic field creates a force on the rotor so that its poles line up with the poles of stator phase. Hence, the advent of SRM (Switched Reluctance Motor) has met the requirement of low cost variable speed drive motor. The main advantages of switched reluctance motor over other motors are, low cost resulting from simple construction, high reliability, high fault tolerance, heat generated in stator is easy to remove, high-speed operation possible. Moreover, SRM also suffers from some disadvantages including high torque ripple due to discontinuous phase current, acoustic noise, vibration etc. Thus, many online and offline controls are reported in the literature for torque ripple minimization in SRM to present SRM as an appliance motor.

Torque pulsation is the most significant at the commutation time when torque developing mechanism is being transferred from one active phase to another. There are dominant source of acoustic noise in an SRM [2]. The methods of achieving power factor improvement can be classified into active and passive types. Compared with a passive PFC converter, an active PFC converter can achieve a high PF and a small size [3].

A CC mode boost PFC converter is mostly used in high and medium-power applications. A CRM boost PFC converter has such advantages as zero-current turning-on of the switch, no reverse recovery of the diode, and high PF [4]. Power Factor Correction (PFC) based Cuk converter fed brushless DC motor (BLDC) drive as a cost effective solution for low power applications [5]. The operation of Cuk converter is described under three modes, along with associated voltage and current waveforms at the time of energy transfer between circuit components [6].

II. PRINCIPLE OF PFC METHOD

The switching control for PFC based converters can be categorized as a variable frequency control and a constant frequency control. The variable frequency control is based on output voltage ripple with constant-on-time (COT) or constant-off-time. Moreover, the converter operates with fixed duty cycle, however, at variable frequency, the converter switch turns on if the condition, $V_{ref}>V_{dc}$ is true, whereas V_{dc} is the DC link voltage and V_{ref} is the set reference voltage. The pulse bursting

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phenomenon is the demerit associated with the COT (Constant on Time) control, i.e., the occurrence of very short off time pulse after COT pulse. Whereas, the constant frequency control is the pulse width modulation (PWM) based control, which are categorized as a voltage based control and a current based control.

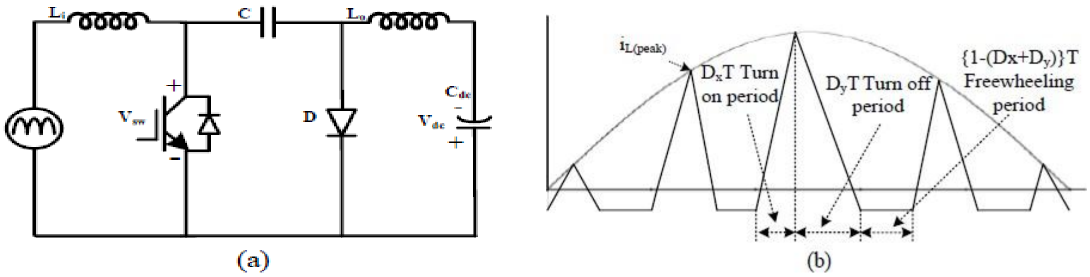

Fig. 1(a), (b) Conventional Cuk converter and Output inductor current during DCM of operation.

III. CONVENTIONAL CUK CONVERTER

The schematic circuit for the conventional Cuk Converter is as shown in Fig. 1(a). The capacitor C_1 is provided to store and transfer the power from input to output. The voltage V_{C1} is always greater than either input or output voltage. The average output to input relations are same as that of a buck-boost converter circuit. The output voltage is controlled by controlling the duty cycle of the switch.

A. Principle of Operation

Non-isolated Cuk converter comprises two inductors, two capacitors, a switch (usually a transistor), and a diode. Its schematic can be seen in Fig. 1.

The capacitor C is needed to transfer energy and is connected by other way to the input and to the output of the converter via the commutation of the transistor and the diode. The inductors L_1 and L_2 are used to convert the input voltage source (V_i) and the output voltage source (C_o) into current sources. At a small time scale an inductor is considered as a current source and it maintains a constant current. This conversion is required because if the capacitor is connected directly to the voltage source, the current would be limited only by the parasitic resistance, resulting in high energy loss. Charging a capacitor with a current source prevents resistive current limiting and its associated energy loss.

As compared with other converters (buck converter, boost converter, buck–boost converter) the Cuk converter can either operate in continuous or discontinuous current mode. It can operate in discontinuous voltage mode (the voltage across the capacitor drops to zero during the commutation cycle.

Cuk converters depend on the inductors in its circuit for giving continuous current. If this inductor is very small / below the "critical inductance", then the inductor current slope will be discontinuous where the current goes to zero. These states of operation are usually not explained in much depth as it is generally not used beyond a demonstrating of why the minimum inductance is crucial.

IV. MODIFIED DUAL OUTPUT CUK CONVERTER FED SRM DRIVE

The new PFC converter fed SRM drive is shown in Fig. 2. The need for a dual output, arises as a special split capacitor converter configuration is used, such that each phase is connected through a single switch and one diode to drive a SRM. The converter circuit comprises of two Cuk converters with one common switch and featured with two output voltages equal in magnitude.

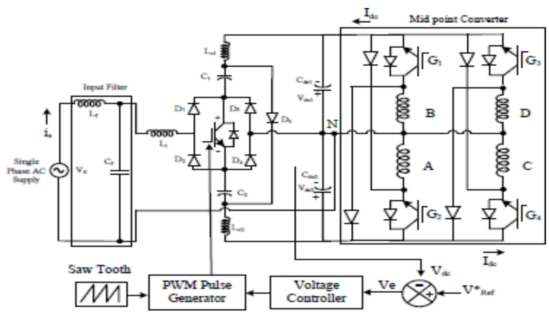

Fig. 1. Modified Cuk converter fed SRM drive

This converter topology is derived from PFC based three phase rectifier topology. This new converter consists of single input inductor operating in CCM to reduce input current ripple. The other circuit components include intermediate capacitors, output

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side inductors and output capacitors. This configuration has added advantage of self-balanced output voltages without any required complex control for voltage balancing. The balanced output voltages have reduced the sensor cost, as while sensing output voltage across one output capacitor gives total DC link voltage. The sensed DC link voltage is compared with reference DC voltage to generate switching pulses for the converter.

A. Operation of Modified Cuk Converter

The converter operation is divided into two half cycles i.e. negative half and positive half of the input voltage waveforms.

- Mode I ((During positive half cycle switch on period t_2-t_1)): During this time interval, positive half cycle is shown in Fig. 3(a). This mode presents the energy flow from mains to inductor Li through diodes D_1, and D_4. The switch on state, is described in this mode during positive half cycle. The charging current for inductor, L_{o1} passes through the switch and output side capacitor C_{dc1}. However, intermediate capacitor is discharged during this mode.
- Mode II (During positive half switch off period t_3-t_2): In the previous mode, capacitor C_1 is left discharged, which is charged from the inductor current i_{Li}. It finds its path through diodes D_1, D_4 and D_5 as shown in Fig. 3(b). The output side inductor L_{o1}, which is charged during Mode I, is discharged through a capacitor, C_{dc1} during this mode. This mode ends with fully charged output capacitor C_{dc1}.
- Mode III (DCM Mode t_4-t_3): Fig. 3(c) shows the circuit operation during this time interval. The output inductor current decreases below zero during this operation mode. During this mode, the converter circuit appears as emulated resistance, which allows constant circuit current.
- Mode IV (During negative half switch on period t_2-t_1): During this time interval, a negative half cycle is associated with converter operation. This mode is shown in Fig. 3(d). This mode describes the switch on period, inductor L_i stores energy, the switch on state, provides the path for input inductor current and the current is flowing through intermediate capacitor C_2 and inductor L_{o2}. The output side capacitor, C_{dc2} is charged during this mode. Moreover, the input inductor current finds its path through diodes D_1 and D_2.
- Mode V (During negative half switch off period t_3-t_2): The stored energy in L_i during Mode V is transferred to intermediate capacitor C_2. Moreover, diodes D_2, D_4 and D_5 provide path for capacitor charging current. The inductor L_{o2} transfers its energy to output side capacitor, $Cdc2$ through diodes D_5 and D_3. The flow of current during this interval, is displayed in Fig. 3(e).
- Mode VI (DCM mode t_4-t_3): Fig. 3(f) shows the DCM with zero output inductor current during negative half cycle.

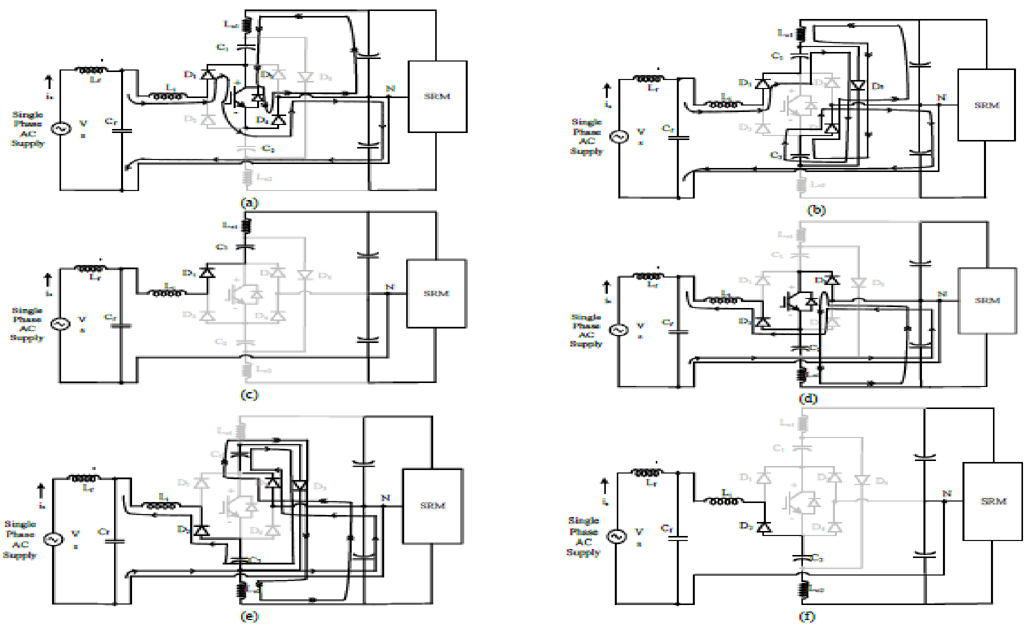

Fig. 3. Converter operating modes during positive half : (a) Mode I (t_2-t_1), (b) Mode II (t_3-t_2), (c) Mode III (t_4-t_3) and during negative half (d) Mode I (t_2-t_1), (e) Mode II (t_3-t_2), (f) Mode III (t_4-t_3).

V. CONTROL ALGORITHM

A. Control of Front End PFC Converter

The fully controlled two equal output voltages of the converter, are varied up to 300 V to obtain motor speed control up to 1500 rpm. It consists of a single voltage feedback loop control. The output of PI controller is finally compared with the high frequency carrier signal at a frequency of 20 kHz. Therefore, the generated PWM pulses are at fixed frequency and a variable duty to obtain control of V_{dc} and PFC at AC mains.

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B. Control of SRM

The control of SRM requires phase to phase commutation of current in accordance with rotor position (θ), which is achieved using position sensors. Here, the optical encoders based sensors are used to determine the rotor position in the proposed drive. The motor control is based on switching sequence as given in table below.

State	Encoder Output		SRM converter Pulses			
	P_1	P_2	G_1	G_2	G_3	G_4
State I	0	0	1	1	0	0
State II	0	1	0	1	1	0
State III	1	0	0	0	1	1
State IV	1	1	1	0	0	1

Fig. 4. Switching states based on encoder output

The split DC converter is used to excite the motor phases with respect to switching sequence. In SRM, a discontinuous nature of the motor phase current, results in high torque ripples when one motor phase is excited at a time, therefore, in the proposed SRM drive, the motor control is based on simultaneous excitation of two phases to get reduced torque ripples.

VI. RESULT

The simulation results proved that Modified Cuk converters output voltage is double the value of Cuk converters output. Thus in turn the new topology has an improved voltage profile with better gain and harmonic profile which can be understood from the Fig. 5.a,b and 6. a,b. Input and output voltages for Cuk and M-Cuk is shown for an input voltage of 300 volts.

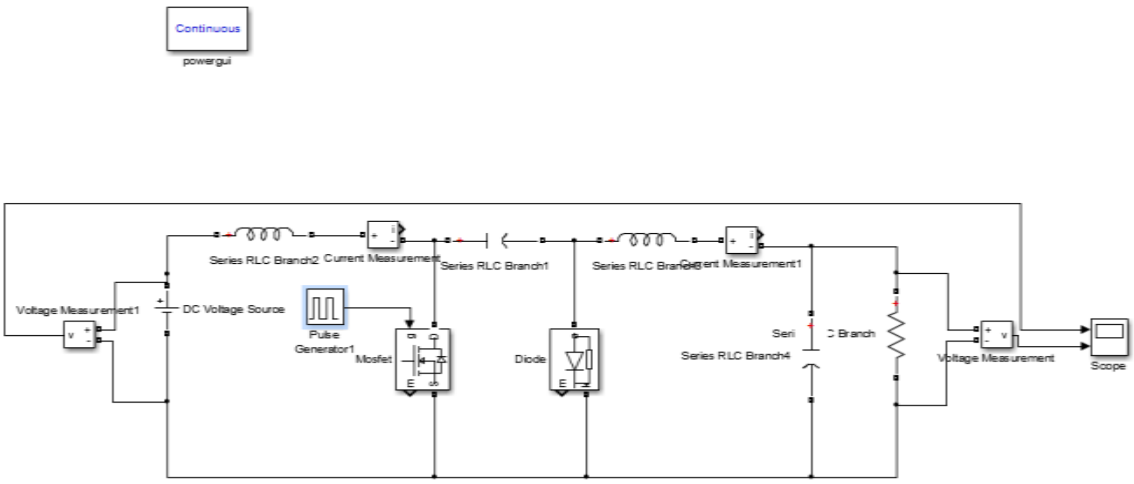

Fig. 5.a Cuk converter simulation circuit

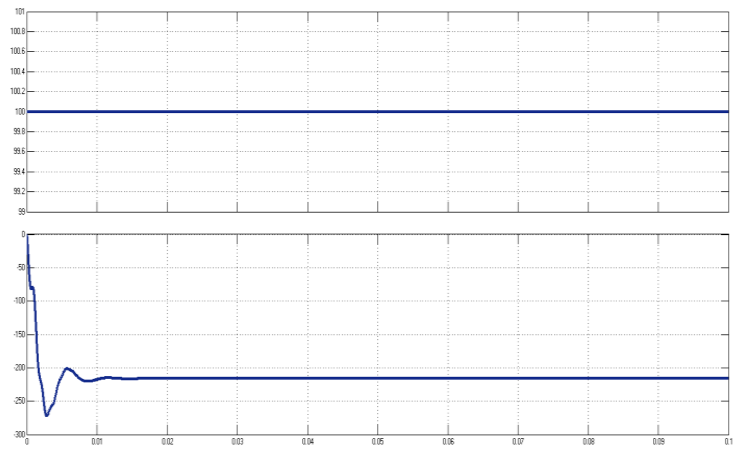

Fig. 5.b Cuk converter with input voltage =300 V, output voltage = 600 V

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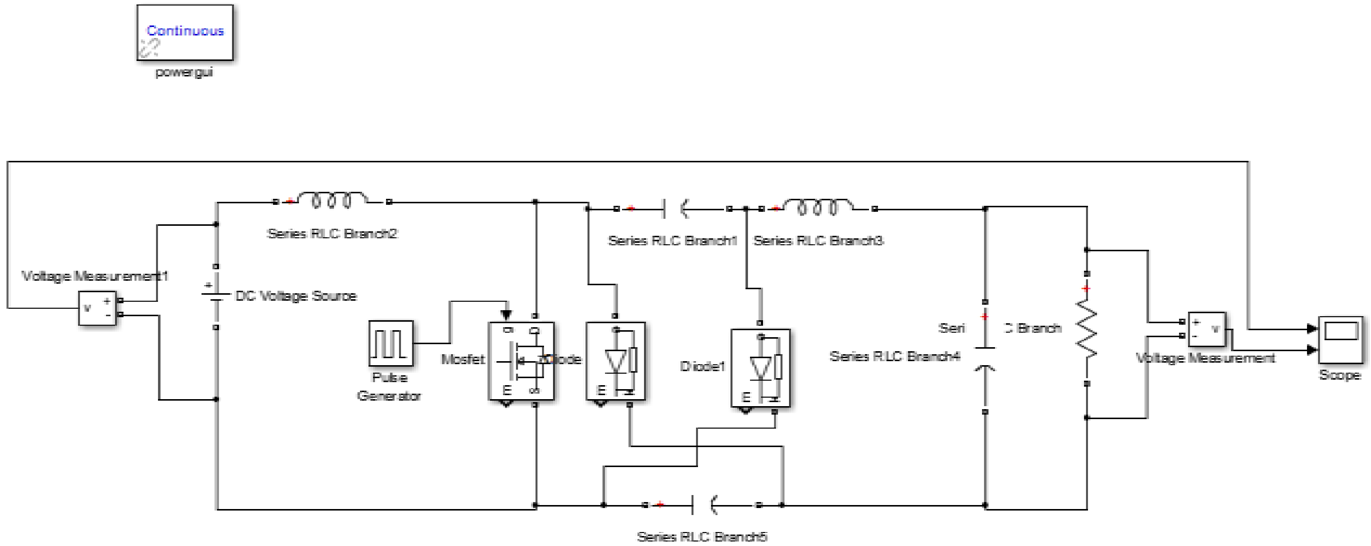

Fig. 6.a M-Cuk converter simulation circuit

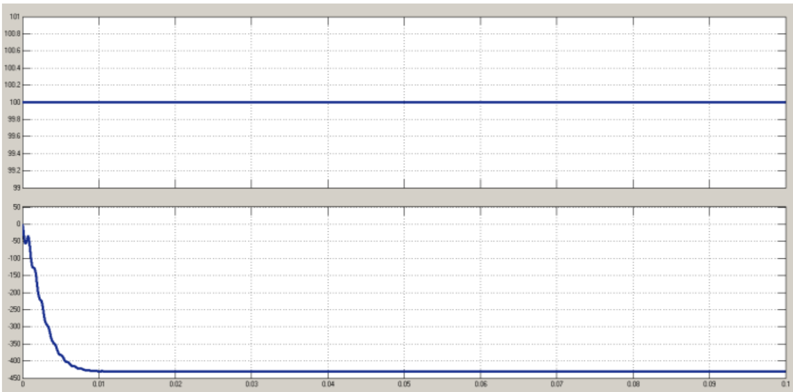

Fig. 6.b M-Cuk converter with input voltage=300 V, output voltage = 1200 V

VII. CONCLUSION

Simulation results have validated performance of new SRM drive. This Cuk converter with two identical output voltages, has been designed with discontinuous output inductor current. The selected inductor, has reduced the size and cost of the magnetic components. The converter output voltage is well regulated by single voltage sensor with inherent wave-shaping of input current. The wide range of speed control has also been obtained while using only one voltage sensor at converter output.

REFERENCES

[1]. Aniket Anand, Bhim Singh, "Modified Dual Output Cuk Converter fed Switched Reluctance Motor Drive with Power Factor Correction", IEEE TRANSACTIONS ON POWER ELECTRONICS, DOI 10.1109/TPEL.2018.2827048, *IEEE Transactions on Power Electronics*.

[2]. I. Husain, "Minimization of torque ripple in SRM drives," *IEEE Trans. on Ind. Electr.*, vol. 49, no. 1, pp. 28-39, Feb 2002.

[3]. K. Yao, X. Ruan, X. Mao and Z. Ye, "Variable-Duty-Cycle Control to Achieve High Input Power Factor for DCM Boost PFC Converter," *IEEE Tran. Industrial Electronics, vol. 58, no. 5, pp. 1856-1865, May 2011.*

[4]. S. F. Lim and A. M. Khambadkone, "A Simple Digital DCM Control Scheme for Boost PFC Operating in Both CCM and DCM," IEEE Trans. Industry Applications, vol. 47, no. 4, pp. 1802-1812, *July-Aug. 2011.*

[5]. V. Bist and B. Singh, "A Unity Power Factor Bridgeless Isolated Cuk Converter-Fed Brushless DC Motor Drive," IEEE Transactions on Industrial Electronics, vol. 62, no. 7, pp. 4118-4129, *July 2015.*

[6]. J. Y. Chai, Y. C. Chang and C. M. Liaw, "On the Switched-Reluctance Motor Drive With Three-Phase Single-Switch Switch-Mode Rectifier Front-End," *IEEE Trans. Power Electronics, vol. 25, no. 5, pp. 1135-1148, May 2010.*