

# **Torque Ripple Reduction in SRM Drive Using LUO Converter**

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**ABSTRACT:** The present work aims at designing and modelling of a bidirectional DC-DC LUO converter for driving a Switched Reluctance Motor. LUO converters are new series of DC/DC Converters with merits like reduced voltage and current ripples, high power density, high voltage transfer gain, high efficiency and simple circuit in structure. In this converter, the voltage gain can be increased on stage by stage using voltage lift technique. The present design aims at improving the efficiency of the Switched Reluctance Motor drive by the incorporation of bidirectional DC-DC LUO converter between the electrical source and the drive system. A C- Dump converter is used to drive the SRM drive. In this paper, a MATLAB simulation study is performed and the results are observed in terms of torque ripple minimization for LUO converter fed SRM drive.

**KEYWORDS:** Bidirectional LUO converter, SRM, torque ripple minimization, C- Dump Converter

## **I. INTRODUCTION**

Switched Reluctance Motors (SRM) have inherent advantages such as simple structure with non-winding construction in rotor side, high tolerance, robustness, low cost with no permanent magnet in the structure, and it operated in high temperatures or in intense temperature variations [1]. The SRM is an electric machine it converts the reluctance torque into mechanical power. In SRM, both the stator and rotor enclose a structure of projected-pole, due to projected poles it produce a high output torque. The torque is formed by the arrangement inclination of poles [1].

Bidirectional dc-dc converters allow transfer of power between two dc sources in either direction [2]. Due to their ability to reverse the direction of flow of current and thereby power the direction of the motor is reversed. Power quality problems have become important issues to be considered due to the recommended limits of harmonics in supply current by various international power quality standards such as the International Electro technical Commission [3] (IEC) 61000-3-2. For class- A equipment (<600 W, 16 A per phase) which includes household equipment, IEC 61000-3-2 restricts the harmonic current of different order such that the total harmonic distortion (THD) of the supply current should be below 19. In all DC/DC converters, the output voltage and power transfer efficiency are limited by parasitic of electronic and power electronic elements. However, in calculation, traditional converters can produce high voltage with high efficiency. LUO converters [4] are new DC/DC converters that overcome above limiter effects and for the increasing of voltage, use relift and triple-lift techniques [4-5]. These converters produce high voltage from low voltage of photovoltaic in operation. In LUO converter with positive output, the input and output voltage are positive [4].

However, fundamental converters such as Boost converter and Buck converter cannot be used in the high-power situation and at the same time have many disadvantages. In recent years, conversion techniques have been developed rapidly and there are plenty of topologies of DC-DC converters. Dr. LUO Fang Lin has invented more than 100 novel topologies of power DC/DC converters, including the well-known series LUO converter, Positive/Negative/Double Output LUO converters etc [4-5].

A LUO converter has been widely used due to its inherent characteristics [6] of voltage lifting many versions of LUO converter voltage lifting technique such as re-lift, super-lift and ultra-lift have been reported in the literature.

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Among them, the Super-Lift LUO Converter is very popular because it has a very high voltage transfer gain [7]. Voltage Lift (VL) technique has been widely used in electronic circuit design. It has provided a good way to solve the problem that the output voltage and power transfer efficiency of DC-DC converters are limited [8]. However, voltage lift technique still has its disadvantages, such as the output voltage increases in arithmetic progression. Along with the development of conversion technique, Super-Lift (SL) technique has shown a more powerful ability than voltage lift technique [5-8].

SRMs require power converters to control the conducting sequence of the stator windings [9]. Asymmetric bridge SRM converters have two switches (plus two diodes) per phase. This converter topology provides the most flexible and effective control to the current waveforms of an SRM but has the highest number of switches [10]. The c-dump circuit has a single switch per phase [11]. The stored magnetic energy in a stator winding is transferred, after the turn-off of a power switch, to the storage capacitor and then sent to the power supply via a step-down dc chopper. The topology could reduce the overall cost of the SRM drive.

## II. PROPOSED LUO CONVERTER FED SWITCHED RELUCTANCE MOTOR DRIVE

In the proposed circuit model shown in Figure 1, input AC supply is converted into the dc supply with the help of the diode bridge rectifier. The DC supply is given to the LUO converter [12]. The LUO converter is used to improve the output quality of the supply. It means in the LUO converter output it contain the less harmonics, less distortion and low ripple. By controlling the LUO converter output, SRM motor output performance is improved. For the LUO converter operation normal PWM generator is used. Thus the C- Dump converter [11] is the efficient converter for the SRM drive.

Here the C- Dump converter is used to drive the SRM motor [12]. The hysteresis current comparator is used to give the rotor position and also it generates the Pulse Signal to the C- Dump converter.

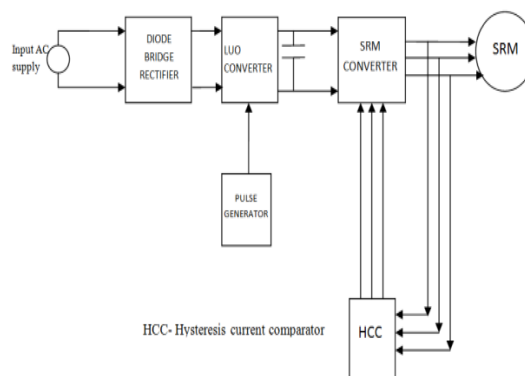


Fig 1.LUO Converter Based SRM Drive

When we control the LUO converter thus the performance of the SRM drive is varied. By controlling the LUO converter SRM drive is easily controlled.

## III. OPERATING PRINCIPLE OF LUO CONVERTER

### 3.1. LUO converter operation

The circuit diagram for the LUO converter [2-8] is shown in Figure 2. In the circuit, S is the main switch and D is the freewheeling diode.

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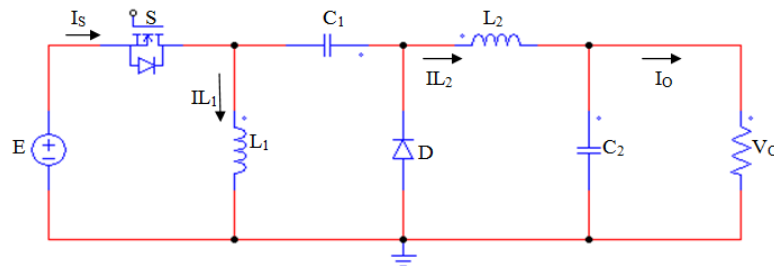


Fig 2.LUO Converter

The energy storage devices are inductors  $L_1$ ,  $L_2$  and capacitors  $C_1$ ,  $C_2$ ,  $R$  is the load resistance. For analyzing purpose the LUO converter can be divided into two modes [13]. When the switch  $S$  is ON, the inductor  $L_1$  is charged by the supply voltage source. The inductor  $L_2$  and capacitor  $C_1$  absorbs the energy from source at the same time. The load power is supplied by capacitor  $C_2$ . During switch  $S$  is in OFF state there is no current flow.

The inductor starts discharging through the freewheeling diode so the capacitor gets charged. The inductor Current  $i_{L2}$  discharges through the capacitor  $C_2$  and the load  $R$ . If we add the additional filter components like capacitor and inductor to reduce the harmonic levels of the output voltage.

### 3.2. Modes of operation

**Mode 1:** when the switch  $S$  is ON, the inductor  $L_1$  is charged by the supply voltage. At the same time, the inductor  $L_2$  is charged through the capacitor  $C_1$  and the source. The capacitor  $C_2$  delivers the load power. The correspondent circuit of LUO converter in method 1 operation is shown in Figure 3.

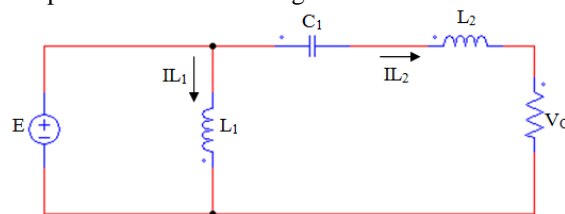


Fig 3.Mode 1 Operation

**Mode 2:** when the switch  $S$  is OFF state, there is no current flow. The inductor starts discharging through the freewheeling diode so the capacitor gets charged. The inductor Current  $i_{L2}$  discharges through the capacitor  $C_2$  and the load  $R$  and the freewheeling diode  $D$  to keep itself continuous. The equivalent circuit of LUO converter in mode 2 operation is shown in Figure 4. In discontinuous conduction mode operation, output is in the form of discontinuous conduction.

In this discontinuous conduction mode diode is not present and inductor discharge throughout  $V_0$  and  $L_2$ . The output period of the LUO buck converter is comprised of an inductor and capacitor.

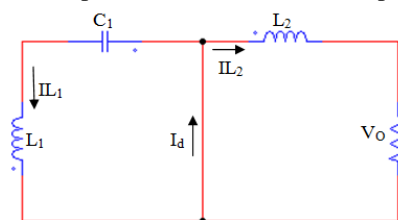


Fig 4 Mode 2 Operation

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The output stage stores and delivers energy to the load, and smoothens out the switch node voltage to produce a stable output voltage. Inductor choice straight influences the amount of current ripple seen on the inductor current, as fine as the current ability of the buck converter itself. Inductors differ from maker to maker in both material and significance, and typically have a tolerance of 20%. Inductors have an inherent DC resistance (known as the DCR) that impacts the performance of the output point. Reducing the DC resistance improves the whole performance of the converter [14-15]. For that function it needs a large load current, it is suggested to choose an inductor with a small DC resistance. The Direct current resistance is lesser for small inductor values, but there is a trade-off between inductance and ripple current; the lower the inductance, the ripple current is high throughout the inductor. Similarly, for the negative half cycle of the supply voltage, switch  $Sw_2$ , inductor  $L_{i2}$ , and diodes  $D_2$  and  $D_n$  conduct.

## IV. ASYMMETRIC BRIDGE CONVERTER FOR SRM DRIVE

Figure 5 shows the asymmetric bridge converter considering only one phase of the SRM. The rest of the phases are similarly connected. Turning on transistors T1 and T2 will circulate a current in phase A of the SRM. If the current rises above the commanded value, T1 and T2 configuration are turned off. The energy stored in the motor winding of phase A will keep the current in the same direction until it is depleted. Hence, diodes D1 and D2 will become forward biased leading to recharging of the source. That will decrease the current, rapidly bringing it below the commanded value. It has the advantage of converting the stored energy to useful mechanical work.

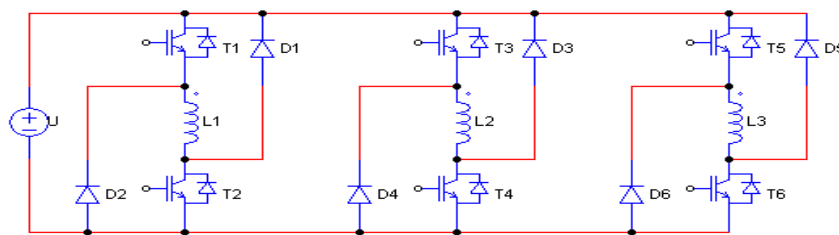


Fig 5 Asymmetric Bridge Converter

While this form of control can be used for current control, the recharging of the source is advantageous when the current has to be turned off rapidly. Such an instance arises when the inductance profile becomes flat or is starting to have a negative slope. Any further conduction of current in such regions entails a loss of energy or production of negative torque, thus reducing the average motoring torque. Note that this converter requires two transistors and two diodes for each phase, resembling the conventional ac motor drives.

## V. SIMULATION RESULTS

### 5.1. Without LUO Converter Fed SRM Drive

The proposed converter fed SRM drive is modeled and simulated using MATLAB / simulink software. The results are obtained for the SRM drive circuit with and without LUO converter.

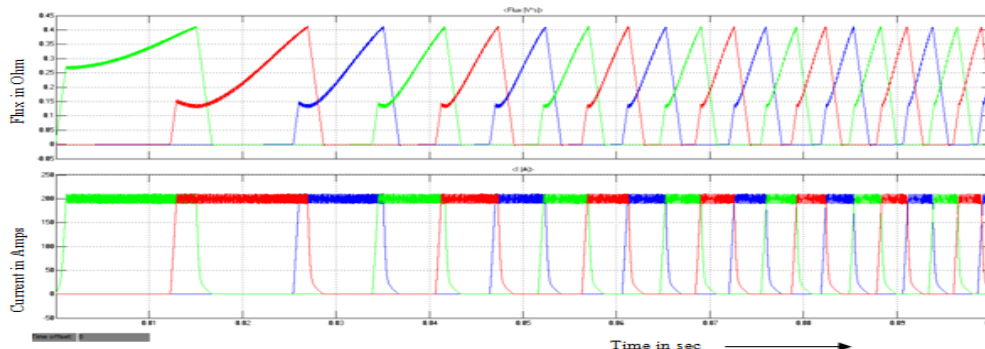


Figure 6. Observed Flux and Current for SRM drive

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Figure 6 gives the observed flux and current waveforms for SRM Circuit without LUO Converter. The current waveform has more ripple content.

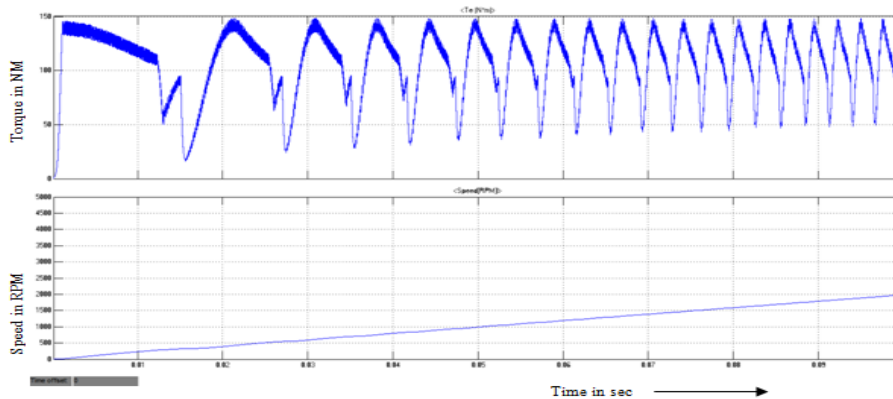


Fig 7 Observed Torque and Speed for SRM drive

Figure 7 shows the simulation results obtained for torque and speed. The torque of the SRM contains more ripples and speed is also not regulated. It takes 0.2 seconds to reach the steady state condition.

### 5.2. LUO Converter Fed SRM Drive

The simulation of LUO Converter fed SRM drive is carried out and the results are observed. Figure 8 shows the waveforms obtained for Flux and Current with LUO converter at the input side of SRM.

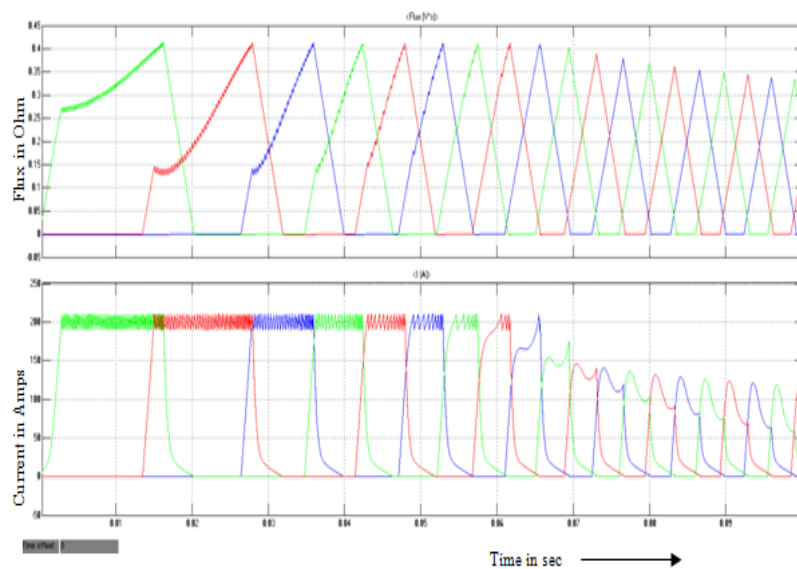


Fig 8. Observed Flux and Current from LUO Converter fed SRM drive

From the results it is clear that, the torque range of the motor is increased and the speed range is also high compared to SRM without LUO converter. The ripple in the flux and current is reduced significantly. Figure 9 shows the torque and speed observed for SRM with LUO Converter. The torque ripple is minimized compared to the conventional SRM drive circuit. The speed reaches the steady state at 0.1 seconds.

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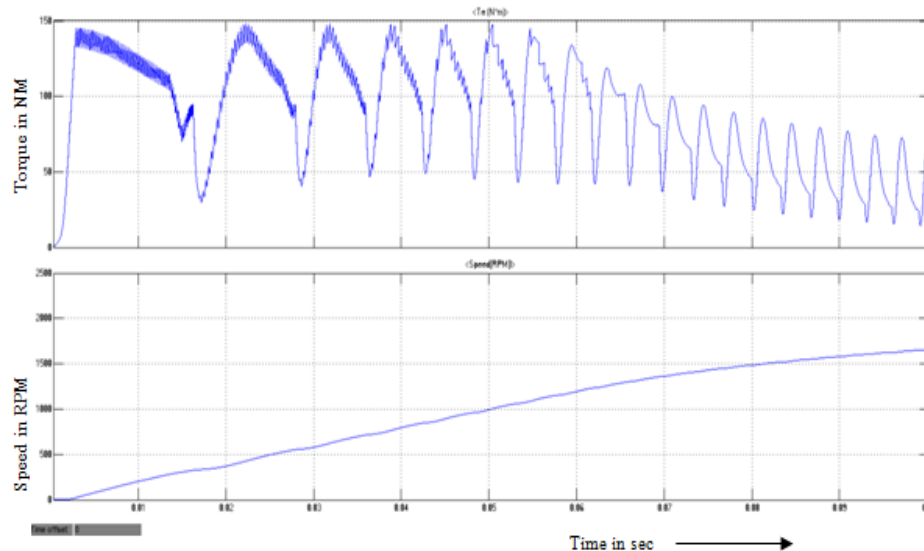


Fig 9. Observed Torque and Speed from LUO Converter fed SRM driv

## VI. CONCLUSION

The bidirectional LUO converter fed Switched Reluctance drive has been studied in this paper. The MATLAB simulation results for SRM drive are observed and compared with results of conventional converter fed SRM. The proposed LUO converter shows better performance in terms of torque ripple minimization. The ripple content can be further reduced, if the LUO converter is implemented with controllers like Fuzzy, Neural Network., etc., The proposed LUO converter is a bridge type and the efficiency can be improved more, when it is replaced by bridgeless LUO converter.

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