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Bidirectional Luo Converter Fed Switched Reluctance Motor

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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 that have very low ripple of voltage and current and have output wave with high quality, high power density and high transfer voltage gain and don't have circuit elements parasitic limits of traditional converters. LUO converters have very high voltage transfer gains in geometric progression on stage by-stage. A C- Dump converter is used to drive the SRM drive. The present design aims at improving the efficiency of the Switched Reluctance Motor drive system by the incorporation of the bidirectional DC-DC LUO converter between the electrical source and the drive system.

Keywords: *LUO converter, SRM, DC-DC converter, C- Dump converter*

1. 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 61000-3-2restricts 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. Among them, the Super-Lift LUO Converter is very

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popular because it has a very high voltage transfer gain. 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. 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].

SRMs require power converters to control the conducting sequence of the stator windings. 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.

The c-dump circuit has a single switch per phase. 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.

2. Proposed LUO 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 diode bridge rectifier.

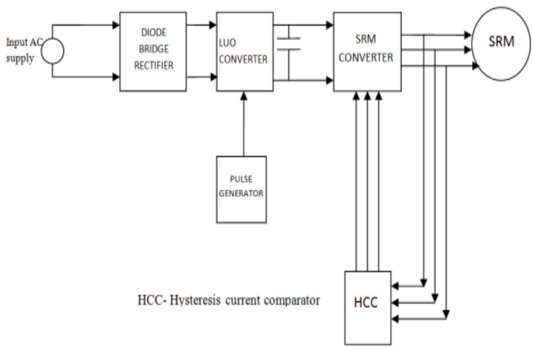

Figure 1. LUO Converter Based SRM Drive

Figure 1 shows the proposed LUO converter based SRM drive.

The DC supply is given to the LUO converter. 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 [7] is the efficient converter for the SRM drive. Here the C-Dump converter is used to drive the SRM motor. The hysteresis current comparator is used to give the rotor position and also it generates the Pulse Signal to the C- Dump converter. 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.

3. 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. The energy storage devices are inductors L1, L2 and capacitors C1, C2, R is the load resistance.

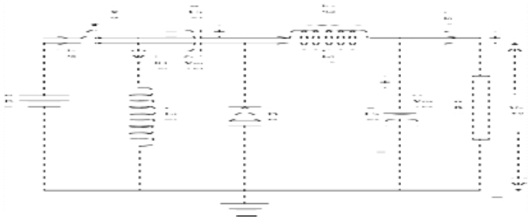

Figure 2. LUO Converter

For analyzing purpose the LUO converter can be divided into two modes. 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.

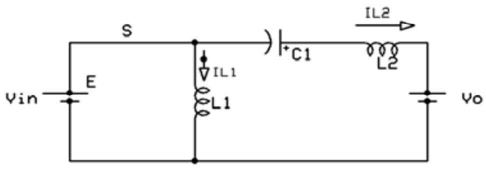

Figure 3. Mode 1 Operation

Mode *2*: when the switch Sis 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.

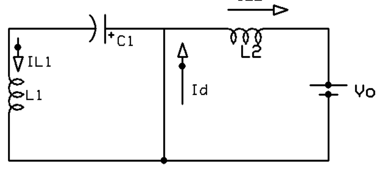

Figure 4. Mode 2 Operation

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. 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, inductorL_{i2}, and diodes D_2 and D_n conduct.

4. C- Dump Converter for SRM Drive

It is derived from the C- Dump converter [9] circuit by eliminating the inductor of the buck converter. The energy is then dumped into the capacitor but is directly utilized by the next phase, rather than being returned to the dc supply as in the conventional C- Dump configuration. Since the C- Dump capacitor voltage is in the range of $2V_{dc}$, its proper utilization significantly improves the drive performance.

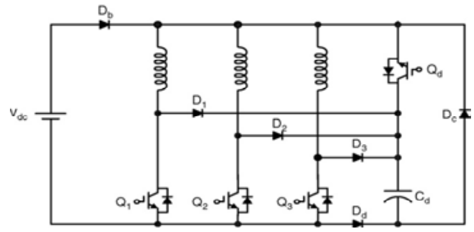

Figure 5. C-Dump Converter

Compared with a modified C- Dump converter, we note that 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 simplified and duplication of the phase currents is enabled in an energy efficient C- Dump converter.

Figure 5 shows the energy efficient C- Dump converter topology, derived from the conventional C- Dump converter [9]. 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 compared to twice the supply voltage ($2V_{dc}$) in the conventional C- Dump converter. In addition, the converter has simple control requirements and allows the motor phase current to freewheel during chopping mode.

5. Simulation Results

5.1. Without LUO Converter Fed SRM Drive

In the results torque range of the motor is reduced and the speed range is also low.

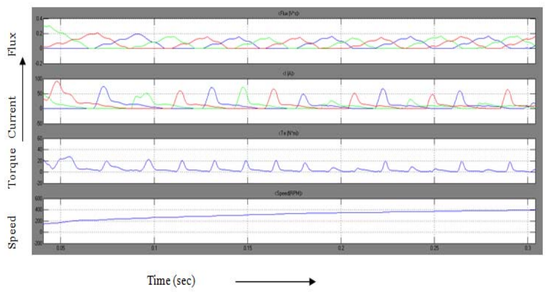

Figure 6. Without LUO Converter Outputs

The ripple in the motor flux is high and also the current range of the motor is low. Without LUO converter circuit the motor takes 0.2 seconds to reach the steady state condition.

5.2. LUO Converter Fed SRM Drive.

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. With LUO converter circuit the motor takes 0.1 seconds to reach the steady state condition when compared to the without LUO converter operation. The acceleration in the torque is high.

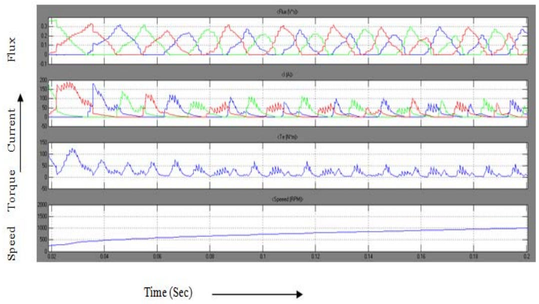

Figure 7. With LUO Converter Outputs

In the given Simulation results the output torque ripple is reduced when compared to the without LUO converter circuit.

6. Conclusion

From this the bidirectional LUO converter fed Switched Reluctance drive has the increased drive efficiency when compared to without LUO converter operation. Here for the LUO converter normal PWM pulse generator is used. In future for the LUO Converter operation SVPWM, NEURAL or FUZZY logic methods will be implemented for improving the performance of LUO converter with SRM drive and also for the Switched Reluctance Drive the space vector modulation technique may be implemented. Due to the implementation of LUO converter the speed of the motor is increased and the torque ripple also reduced. Bridge LUO converter has to be replaced with Bridgeless LUO converter so that the power factor is improved when compared to the conventional converters.

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