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Research paper

Performance evaluation of multiple lift push-pull LUO converters for automotive applications

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Abstract

Solar energy power generation has several advantages such as low maintenance costs; environment friendly, no rotating parts in con-struc-tion gives no noise. In recent years, solar power is used to charge the batteries of electric vehicles and instead of internal combus-tion En-gines the Electric motors such as DC motors, Brushless DC (BLDC) motors are used for driving the vehicles. The Multiple Lift Push-Pull Luo (MLPPL) converter is a DC-DC converter, which combines both switched capacitor and voltage lift techniques. Further, the MLPPL converters can be used in high power density, high power efficiency and voltage transfer gain applications. In this work, a MLPPL convert-er integrated with voltage source inverter (VSI) loading BLDC motor drive for automotive applications have been pro-posed. Further, the simulation of the proposed design has been carried out using MATLAB/Simulink Software. The torque of the BLDC motor has been varied and the performance of the MLPPL converter has been analyzed. Results demonstrate that the proposed design is capable to operate over a wide range of torque, which fulfills the application of Electric Vehicle.

Keywords: *DC-DC Converter; Push-Pull Luo Converter Switched Capacitor; BLDC Motor; Torque-Speed.*

1. Introduction

Photovoltaic system generates electricity with the help of sunlight without any harm to the environment and it gains more affinity towards renewable energy power generation [1]. Solar energy power generation has several advantages such as low maintenance costs, environment friendly, no rotating parts in construction gives no noise. In recent years, solar power is used to charge the batteries of electric vehicles and instead of Internal combustion Engines the Electric motors such as DC motors, Brushless DC motors are used for driving the vehicle [2]. Brushless DC (BLDC) motors have become more popular due to its advantages such as high power density, high efficiency, low maintenance etc. In the BLDC motor, the accurate and instantaneous ripple-free torque has been developed. Conventional converters such as Buck, Boost and Buck-Boost have limited range of output voltage and power transfer efficiency due to the effect of parasitic elements. DC-DC Luo converters such as Positive output Luo converters, negative output Luo converters etc have been successfully developed with the voltage-lift technique [3] which results in good performance such as high voltage transfer gain (VTG), low ripple voltage and current. Further, there are many topologies of DC-DC converters; the Self-Lift Luo Converter is very popular due to its high voltage transfer gain [4].

Sheeba et al. (2013) [5] have implemented the digital control of three phase BLDC motor. The motor is controlled in all the four quadrants without any loss of power and energy is recovered back during regenerative braking period. Further, the authors have discussed the advantages of Digital Signal Processor and PIC microcontroller. Chun et al. (2014) [2] have developed sensorless control of BLDC motor for an automotive application. In the sensorless operation, a potential start-up method with a high starting torque is suggested and rotor position is aligned at standstill for maximum starting torque without an additional sensor. Further, the authors have implemented a single chip DSP controller and have discussed the feasibility of the sensorless techniques.

Singh et al. (2015) [6] have proposed reduced sensor configuration of a power factor correction (PFC) based zeta converter for BLDC motor drive for low power applications. Further, the authors have found that the speed of the BLDC motor is controlled by varying the dc-link voltage of the voltage source inverter (VSI) feeding BLDC motor drive. Also, the authors have adopted low frequency switching of the VSI to achieve the electronic commutation of BLDC motor for reduced switching losses. Kumar and Singh (2016) [1] have proposed a photovoltaic (PV) array fed water pumping system utilizing a zeta converter as an intermediate DC-DC converter to extract the maximum power from the PV array. Further, the authors have employed BLDC motor to drive a centrifugal water pump and the motor drive is soft started using incremental conductance maximum power point tracking algorithm. Also, the authors have analyzed the performance of BLDC motor drive under dynamic conditions.

Luo and Ye (2004) [8] have introduced a new series of DC-DC converters- Positive Output (P/O) multiple lift push-pull switched capacitor DC-DC Luo converters. Further, the authors have found that a new series of DC-DC converters is suitable for industrial applications with high output voltage. Kumar et al. (2016) [9] have designed and evaluated the performance of PI controller for Multiple Lift main series 2 and 4 Lift push pull switched capacitor Luo converter.

The multiple self lift push pull Luo converters are constructed with a switched capacitor results small in size with very high power density. The objective of this work is to evaluate the performance of Multiple Self-Lift Luo Converter for Automotive Applications.

2. Research methods

2.1. Elementary circuit of P/O push-pull luo converter

The elementary circuit and its equivalent circuits during Switch-on and switch-off [8] are shown in Figure 1. There are several lift circuits for P/O multiple lift push-pull luo converter such as 2-lift circuit, 4-lift circuit, 8-lift circuit etc. In all the circuits S acts as a main switch and other switches acts as slaves. The masters and slaves operates alternatively with each other. If the master switch S is on and slaves off. Two switches S and S_1 operate in the push-pull state [8].

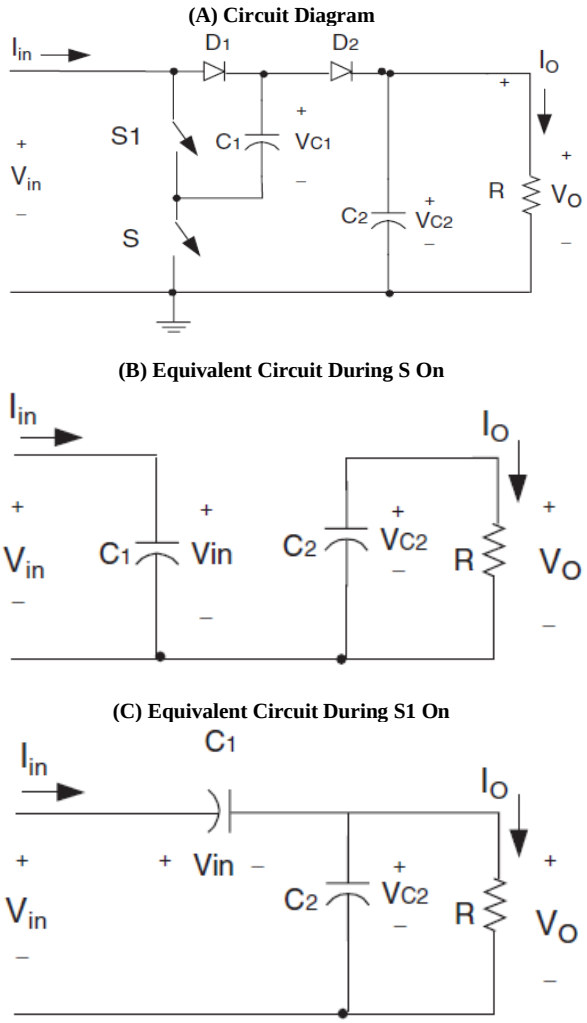


Fig. 1: Elementary Circuit and its Equivalent Circuits During Switch-on and Switch-Off.

The voltage across capacitor C_1 is charged to V_{in} during switch on. The voltage across capacitor C_2 is charged to $V_O = 2V_{in}$ during switch off. Therefore, the output voltage is,

$$V_o = 2V_{in} \tag{1}$$

Considering the voltage drops across the diodes and switches, we combine all values in a figure of ΔV_1. The real output voltage is

$$V_o = 2V_{in} - \Delta V_1$$

$$= 2V_{in} - (V_{D1} + V_s + V_{S1} + V_{D2})$$

$$= 2V_{in} - (2V_s + 2V_d) \tag{2}$$

2.2. Proposed multiple lift push-pull luo converter fed BLDC motor drive

Figure 2 shows the proposed multiple lift push-pull luo converter fed BLDC motor drive. The proposed system is sourced by a Photovoltaic module. The input voltage ranges around 80V. For convenience of explanation, the circuit can be divided into two parts; P/O multiple lift push-pull luo converter and VSI fed BLDC motor drive. The converter boosts the source input voltage and output voltage of the multiple lift push-pull luo converter V_o= 2Vin. Hence the output voltage at the capacitor C_2 is 80V. The output capacitor of the multiple lift push-pull luo converter acts as a DC link capacitor for voltage source inverter fed BLDC motor drive. This dc-link capacitor voltage powers three phase six pulse converter which is controlled based on the position of the rotor. Generally the hall sensors are used to detect the rotor position of the BLDC motor. The switching pattern of inverter depends on the rotor position signal and torque of the motor [5].

The proposed system is specially designed for automotive applications. Hence the torque of the BLDC motor changes with respect to the load. Therefore the change in torque affects speed of the motor. The control of BLDC motor drive is classified into two parts; control of front end multiple lift push-pull luo converter and control of voltage source inverter with respect to rotor position. The speed of BLDC motor is controlled by varying the dc-link voltage of voltage source inverter [6]. The dc-link voltage of the voltage inverter is changed by varying the duty cycle of the master switch S and Slave switch S1. Hence the BLDC motor drive has a wide range of control over torque and speed.

Table 1:. Circuit Parameters

Parameter's Name	Symbol	Value
Input Voltage	V_{in}	80V
Capacitors	C_1, C_2	220uF, 1000uF
Multiple self-lift push pull luo converter Output Voltage	Vc_o	160V
Voltage Source Inverter Output Voltage	Vo	80V

The proposed circuit parameters are tabulated in the table 1. In the P/O multiple self lift push pull luo converters two capacitors C_1=220uF and C_2=1000uF are used for 2-lift process. The switching frequency of the voltage source inverter fed BLDC motor drive depends on the position of the rotor.

3. Results and analysis

Figures 3(a) and (b) show the output voltage and output current of the P/O multiple self lift push-pull luo converter with respect to time. The PV system is modeled using the standard circuit parameters and it feeds around 80V to the converter. Further, it is observed that the P/O multiple self lift push-pull luo converter produces output voltage of 160V and output current of 0.8A. The output of the multiple self lift push-pull luo converter powers the VSI fed BLDC motor drive. Hence the dc-link capacitor voltage (input voltage of the VSI) is same as the output voltage of the converter. Figure 4 show the stator phase voltages, stator phase currents, speed in RPM and Electromagnetic torque in Nm of the BLDC drive with respect to time.

Further, it is observed that the stator phase voltages V_a, V_b and V_c scopes around 80V and Stator phase current I_a, I_b and I_c scopes around 1.6A. The speed of the BLDC motor drive is observed as 1035RPM for the 1Nm mechanical torque. Further it is seen that the change in mechanical torque from 1 Nm to 1.2 Nm changes the speed of BLDC motor drive from 1035 RPM to 1025 RPM. Also, the mechanical torque from 1.8 Nm changes the speed of drive from 996 RPM to 990 RPM.

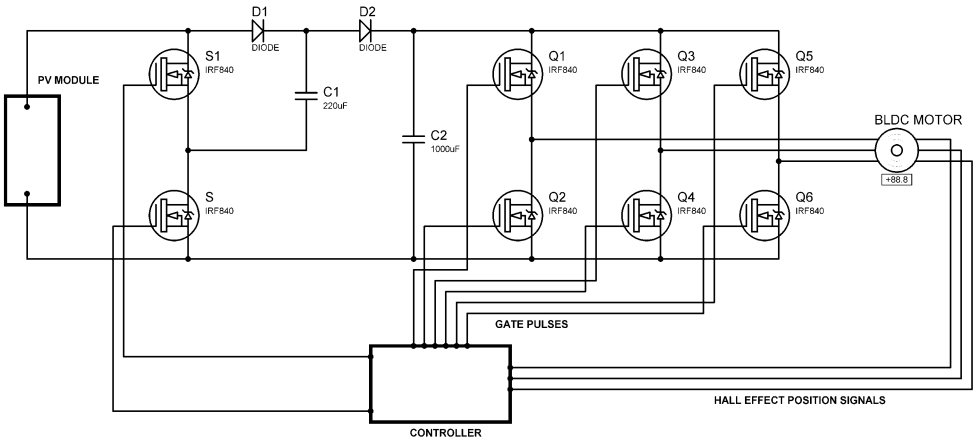


Fig. 2: Proposed Multiple Lift Push-Pull Luo Converter Fed BLDC Motor Drive.

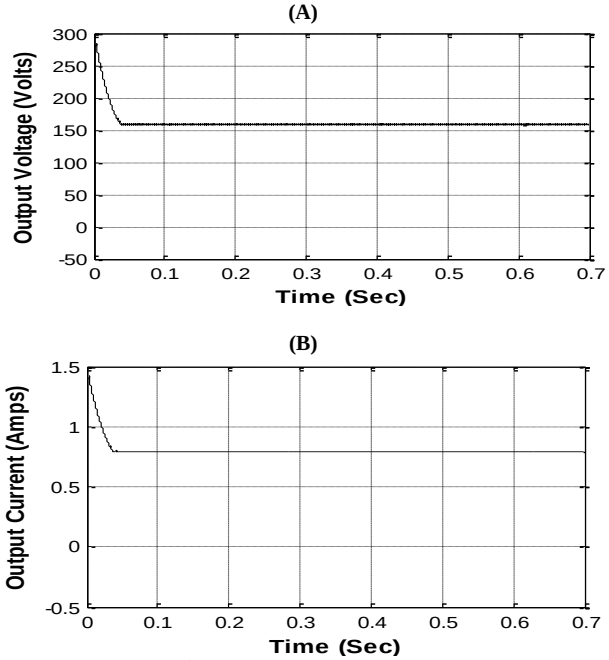
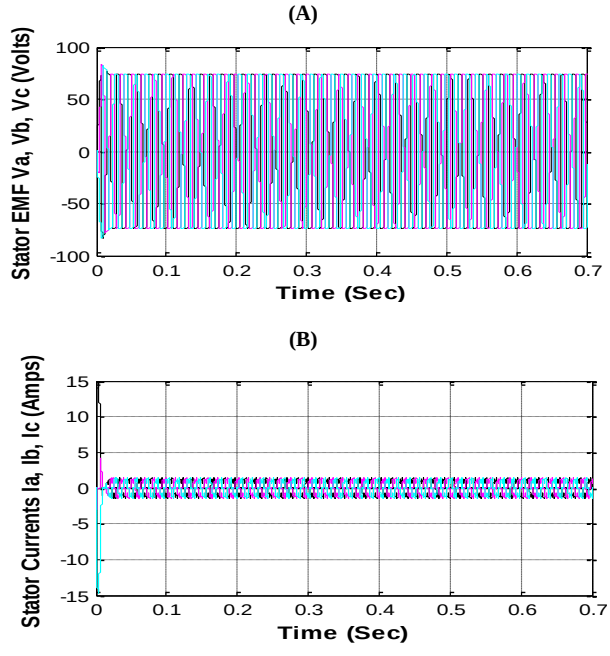


Fig. 3: P/O Multiple Lift Push-Pull Luo Converter (A) Output Voltage (B) Output Current.



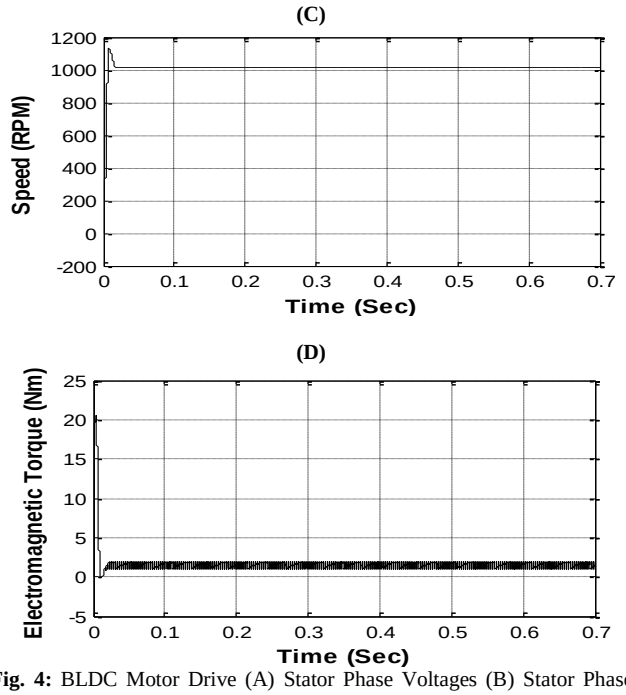


Fig. 4: BLDC Motor Drive (A) Stator Phase Voltages (B) Stator Phase Currents (C) Speed in RPM (D) Electromagnetic Torque in Nm

By applying the Mechanical Torque to the BLDC motor drive, the speed of the motor gets decreased. The mechanical Torque (Nm) is varied from 1 Nm to 2 Nm and speed of the BLDC motor drive is observed and tabulated in Table 2. It is seen that the speed of the BLDC motor drive decreases with increase in mechanical torque. The speed of the BLDC drive is maintained constant by varying duty cycle of the main switch in multiple self lift push-pull luo converter. For automotive application a wide range of control over speed and torque is required. Hence the proposed system perfectly suits automotive applications.

Table 2: Speed Vs Torque of the Proposed BLDC Motor Drive

Speed (RPM)	Mechanical Torque (Nm)
1035	1
1025	1.2
1016	1.4
1007	1.6
996	1.8
990	2

4. Conclusion

Brushless DC motor (BLDC) is suitable for low and medium power applications. It has several advantages such as low maintenance, high toque to inertia ratio, wide range of speed control etc. BLDC motor has a wide range of applications such as industrial

tools, medical equipments, Electric vehicle, Aerospace equipment etc. Positive output multiple lift push-pull luo converters is a DC-DC converter which combines both switched capacitor and voltage lift techniques. In this work, a positive output multiple lift push-pull luo converters integrated with voltage source inverter (VSI) driving BLDC motor has been designed and simulated using MATLAB/Simulink Software. The input and output parameters such as stator phase voltages, stator phase currents, speed and electromagnetic torque of BLDC motor drive has been obtained. Further, the torque of the BLDC motor has been varied and the performance of BLDC motor has been analyzed. Results demonstrate that the speed of the BLDC motor drive decreases with increase in mechanical torque. Further, the proposed multiple self lift push-pull luo converter fed BLDC motor drive is capable to operate over a wide range of torque which fulfils the application of Electric Vehicle.

References

[1] Kumar, R., & Singh, B. (2016). BLDC Motor-Driven Solar PV Array-Fed Water Pumping System Employing Zeta Converter. IEEE Transactions on Industry Applications, 52(3), 2315-2322.

[2] Chun, T. W., Tran, Q. V., Lee, H. H., & Kim, H. G. (2014). Sensorless control of BLDC motor drive for an automotive fuel pump using a hysteresis comparator. IEEE transactions on power electronics, 29(3), 1382-1391.

[3] He, Y., and F. L. Luo. "Analysis of Luo converters with voltage-lift circuit." IEE Proceedings-Electric Power Applications 152.5 (2005): 1239-1252.

[4] Luo, F. L. "Double output Luo-converters-voltage lift technique." Power Electronic Drives and Energy Systems for Industrial Growth, 1998. Proceedings. 1998 International Conference on. Vol. 1. IEEE, 1998.

[5] Joice, C. S., Paranjothi, S. R., & Kumar, V. J. S. (2013). Digital control strategy for four-quadrant operation of three-phase BLDC motor with load variations. IEEE transactions on industrial informatics, 9(2), 974-982.

[6] Singh, B., & Bist, V. (2015). Power quality improvements in a zeta converter for brushless DC motor drives. IET Science, Measurement & Technology, 9(3), 351-361.

[7] Singh, B., Bist, V., Chandra, A., & Al-Haddad, K. (2015). Power Factor Correction in Bridgeless-Luo Converter-Fed BLDC Motor Drive. IEEE Transactions on Industry Applications, 51(2), 1179-1188.

[8] Luo, F. L., & Ye, H. (2004). Positive output multiple-lift push-pull switched-capacitor Luo-converters. IEEE Transactions on Industrial Electronics, 51(3), 594-602.

[9] Luo, Fang Lin. "Luo-converters, voltage lift technique." Power Electronics Specialists Conference, 1998. PESC 98 Record. 29th Annual IEEE. Vol. 2. IEEE, 1998.