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DESIGN AND IMPLEMENTATION OF BRIDGELESS BUCK CONVERTER WITH FUZZY CONTROLLER FED PMDC DRIVE

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Abstract

This paper presents the Fuzzy controller based bridgeless buck converter has been estimated and the performance of the converter is analyzed. This converter has advantages like reduced switching losses, stresses and EMI. The method to predict the steady state and dynamic performance of the converter fed with PMDC motor operation has been presented. The proposed converter has been analyses with the closed loop and open loop condition. The simulation study indicates the superiority of fuzzy control over the conventional control methods. A prototype Buck converter is designed and experimentally demonstrated. The prototype is tested for the steady state and transient conditions. Comparison between experimental and simulations show a very good agreement and the reliability of fuzzy controller.

Keywords:

Power Electronics, Buck Converter, Fuzzy Controller, Bridgeless Converter, MATLAB

1. INTRODUCTION

Recently for medium and high power applications at high voltages, buck converters have been found a realistic solution. The research in this field has been shown more interest by many researchers in developing the load independent converters using various concepts. They are gaining extensive popularity among their excellent performance like output voltage with negligible THD, reduced rippled and regulated de output voltage, reduced voltage stress and low EMI emission. It has been suggested to design Resonant Converter with reactive components for better regulation. In order to overcome the above limitations, the bridgeless converter is found to be reliable due to various inherent advantages. Among all the topologies of the buck converters, the bridgeless converter shares the advantages of both the pure series converter and pure parallel converters.

Yungtaek Jang et al [1] have demonstrated active clamp ZVS DC-DC converter. The steady state analysis was presented for ZVS Buck converter. There is no possible of load independent operation. The converter operates at duty cycle >0.5, above its operation the converter fails to instability. L. Huber et al [2] have developed the buck Converter with closed loop operation using Power factor control. Resonant Converter is compared with open loop and closed loop. Here the load variation and load independent operation not presented, and there was no static and dynamic analysis. Later, W. W. Weaver et al [3] have demonstrated current source buck converter with open loop operation. The AC equivalent circuit analysis and fundamental mode approximation (FMA) analysis was derived used to the modeling the converter and compared. The evaluation of static and dynamic performance was not provided. Later T.S.Sivakumaran et. al. [4] have been developed a CLC SPRC using FLC for load regulation and line regulation. The performance of controller has been evaluated and found that the load independent operation may not be possible. The FLC based Zero Voltage Switching quasi-resonant converter has been demonstrated in [5-8]. Buck and boost DC-DC converter based fuzzy logic controller have been developed by Ismail Atacak et al [9]. Buccella, C et al [10] have developed the DC/DC resonant converter for the renewable energy source applications. The fuzzy controller was used to regulate the output voltage with constant level if the input voltage varies within a large range change. The transient and steady state performance of the converter was found with fuzzy and PI controllers.

It is clear from the above literatures that the output voltage regulation of the converter against load and supply voltage fluctuations have important role in designing high-density power supplies. The bridgeless converter is expected to have the speed of response, voltage regulation and better load independent operation. Keep the above facts in view, the buck converter has been modeled and analyzed for estimating various responses. A Bridgeless Buck Converter is implemented and the experiment results are compared with the simulation results. The simulation results agree with the experimental results.

2. PROPOSED SYSTEM

A bridgeless buck converter improves the low voltage efficiency of the buck converter by reducing the conduction loss through minimization of the number of simultaneously conducting semiconductor components is introduced. Because the proposed bridgeless buck rectifier also works as a voltage doubler, it can be designed to meet harmonic limit specifications with an output voltage that is twice that of a conventional buck converter. As a result, the proposed rectifier also shows better hold-up time performance and the switching losses of the primary switches of the downstream AC/DC output stage are still significantly lower than that of the counterpart. MOSFETs are required to implement this topology in universal-line applications exhibits reduced losses and are counterparts rated below. In fact, the bridgeless rectifier topology will become attractive from a performance point of view once high voltage SiC and/or GaN devices become available in the future. To verify the operation and performance of the proposed bridgeless buck converter, an experimental prototype circuit was built more expensive.

3. BLOCK DIAGRAM

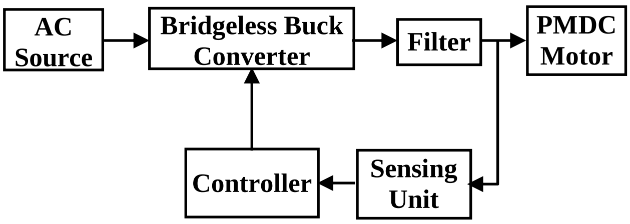

Fig.1. Block Diagram of the Proposed Converter

Input AC Voltage (230V) is given to the Bridgeless Buck converter unit and it's providing the operation. In the Bridgeless Buck Converter two switches has been employed between the diodes. The two switches have been connected anti parallel to each other. The pulse to the switches is given by pulse width modulation techniques. The inductance and capacitor is used as a filter. The capacitor is connected in parallel to each other to the drive and the inductance is connected in series to the switches. The speed sensor has been provided to measure the speed of the motor and converted to voltage to the controller unit to provide proper pulses for the switches. The Pulse Width Modulation Technique with micro controller has been employed to provide pulse to the gate terminals of the switches. The PMDC motor is employed as load. The output of the circuit is connected to the terminals of the motor.

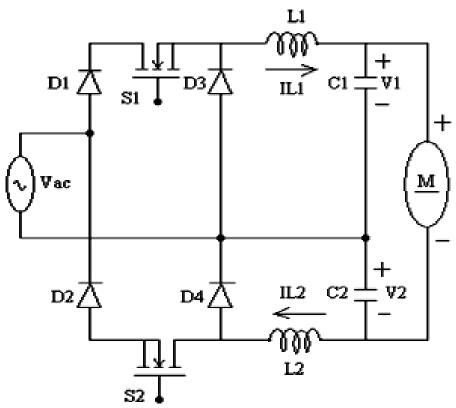

Fig.2. Open Loop Circuit Diagram of the Proposed Converter

The circuit diagram of the proposed DC/DC converter is shown in Fig.2. It is based on the full bridge converter. The circuit consists of two switches and four diodes. The diodes can be connected in series parallel to each other. The switches can be connected between the diodes in which it is connected anti-parallel to each other. The inductor is connected in series with the two switches to the load. The capacitor is connected in parallel with each other and to the load. From the drive i.e. motor output speed is measured with speed sensor and converted into voltage give to the controller unit. Hence the controller can compares the error voltage and reference voltage and adjust the speed of the drive.

4. FUZZY LOGIC CONTROL

Fuzzy control involves three stages: fuzzification, inference or rule evaluation and defuzzification. Bridgeless converter is modeled using MATLAB software. Fuzzy control is developed using the fuzzy toolbox. The fuzzy variables 'e', 'ce' and 'Δu' are described by triangular membership functions. Table.2 shows the fuzzy rule base created in the present work based on intuitive reasoning and experience. The linguistic labels are divided in to seven groups. These are NH-Negative High, N-Negative, NL-Negative Low, Z-Zero, PL-Positive Low, P-Positive, PH-Positive High.

It can inferred that the output voltage is far from the reference value, then the change of switching frequency (Δu) must be large so as to bring the output to the reference value quickly. The output voltage approaches the reference value, and then a small change of switching frequency is necessary and if the output voltage is near the reference value and is approaching it rapidly, then the frequency must be kept constant so as to prevent overshoot. It is also seen that if the output voltage changes even after reaching the reference value then the change of frequency must be changed by a small amount to prevent the output from moving away.

Table.1. Fuzzy Rules

	Error (e)							
Change in error (ce)		NH	N	NS	Z	PL	P	PH
	NB	NH	NH	NH	NH	N	NL	Z
	N	NH	NH	N	N	NL	Z	PL
	NL	NH	N	NL	NL	Z	PL	P
	Z	NH	N	NL	Z	PL	P	PH
	PL	N	NL	Z	PL	PL	P	PH
	P	NL	Z	PL	P	P	PH	PH
	PH	Z	PL	P	PH	PH	PH	PH

5. RESULT AND DISCUSSION

The closed loop simulation using FLC is carried out using MATLAB/Simulink software. Depending on error and the change in error, the value of change of switching frequency is calculated. The Fuzzy set parameters instruction and function blocks available in MATLAB are used to update the new switching frequency of the pulse generators. The entire system is simulated with a switching frequency of 100 KHz.

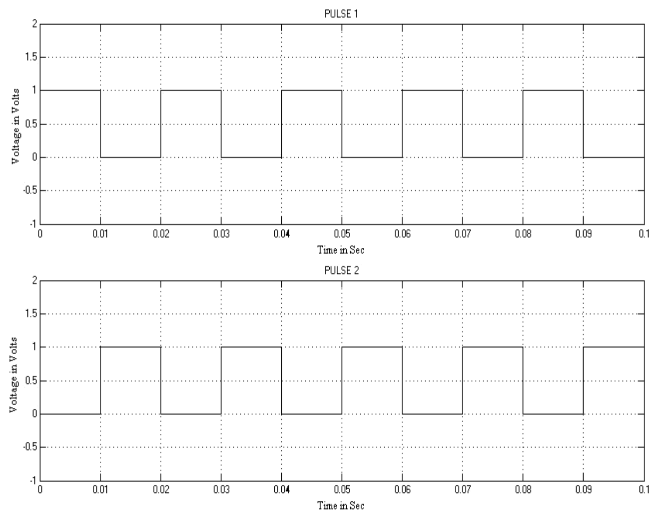

Fig.3. MOSFETS Switching Pulses

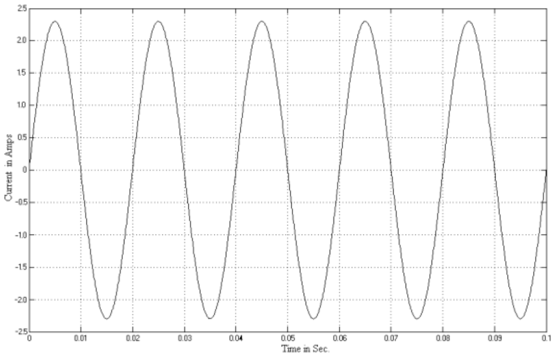

Fig.4. Current through Inductor

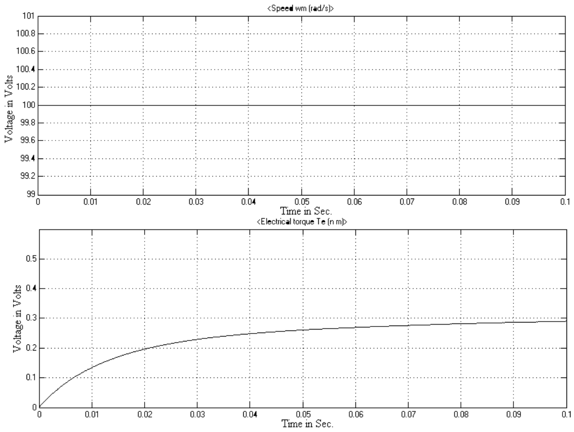

Fig.5. Motor Output Voltage and Speed Waveform

6. HARDWARE IMPLEMENTATION

The performance of the proposed rectifier circuit that was designed to operate from a universal AC input supply with a 12V output. Fig.6 shows the schematic diagram and component details of the experimental prototype circuit. Since the drain voltage of switches S_1 and S_2 are clamped to the voltage difference between the input voltage and output capacitor voltage, the peak voltage stress on switch S_1 and S_2 can be as high compare to input voltage. An IRF540 MOSFET was used as switching devices in the buck converter. Since buck converter diodes D_3 and D_4 must block both the same peak voltage stress and conduct the same peak current as the switches, MUR4100 was used. At low line voltage, the reverse-recovery losses are high, the reverse voltage across the buck diode reduced the voltage, which is much smaller than that in its boost converter voltage. The inductor was built using a pair of ferrite cores and 24 turns of Litz wire. Litz wires were employed to reduce fringe effects near the gap area of the inductors [5]. Three aluminum capacitors were used for output capacitors C_1 and C_2 for their ability to meet the hold-up time requirement of the load. Because capacitors C_1 and C_2 are connected in series, the capacitance seen from the second stage converter is 1500 μF. Although the total capacitance of capacitors C_1 and C_2 is 6000 μF, the overall volume of the capacitors is not large since they are low-voltage capacitors.

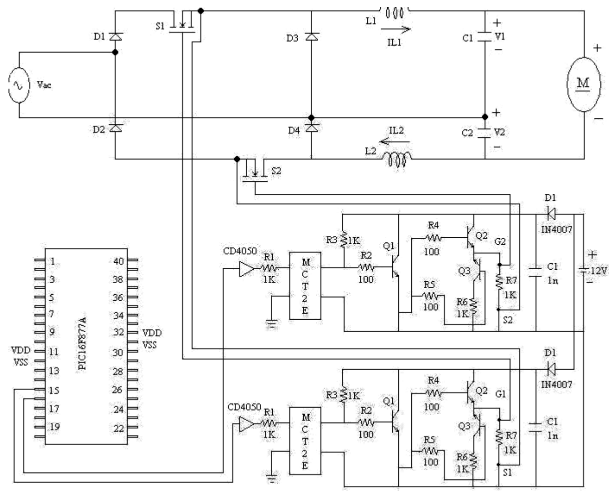

Fig.6. Overall circuit diagrams for bridgeless buck converter

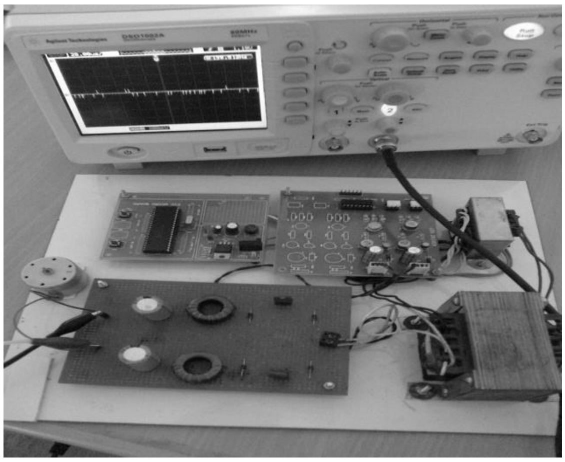

Fig.7. Hardware module for Bridgeless Buck Converter

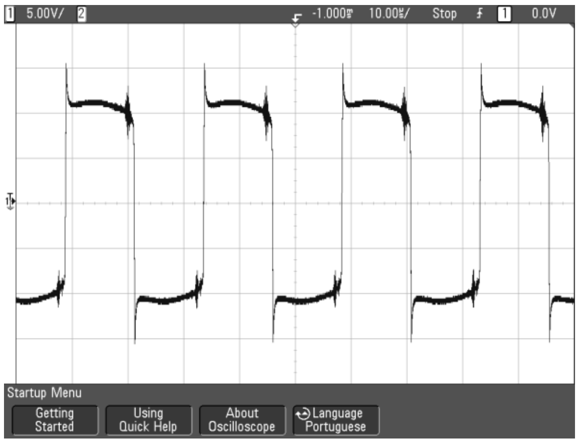

Fig.8. MOSFET Switching Pulse CH1: voltage [Volt.scale:2/DIV.]

The independent controllers with a common output voltage reference actively balance the voltages across capacitors C_1 and C_2 so that the voltage imbalance by the mismatched output inductors can be completely eliminated. The power supply that delivers 12V DC output from 115V and 230V AC inputs meets the efficiency requirements of CSCI Gold specifications over the entire load and input ranges. The above figures shown the fuzzy controller output signal for this test. These figures show the good dynamic performance of the controller. It is clearly seen form the above figures the current and output voltage contains harmonic, this harmonics effect relatively hard for the whole circuit, because non-linear loads affect the circuit. Fig.9 and Fig.10 presents the converter current and output voltage for buck converter, its measure from the bridgeless inverter.

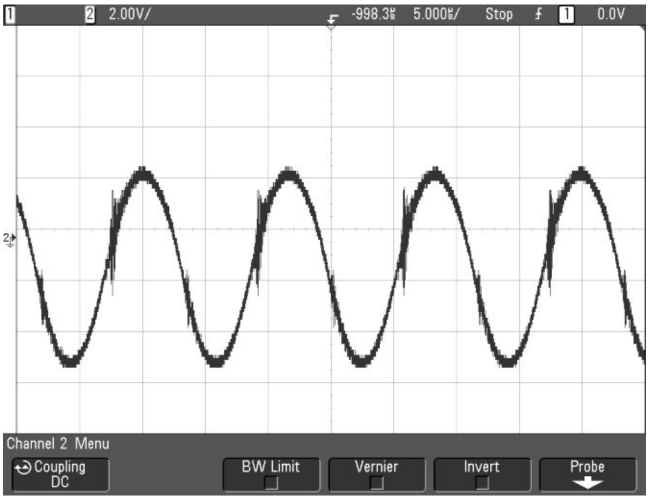

Fig.9. Current through Inductor CH1: current [amp.scale:0.5A/DIV.]

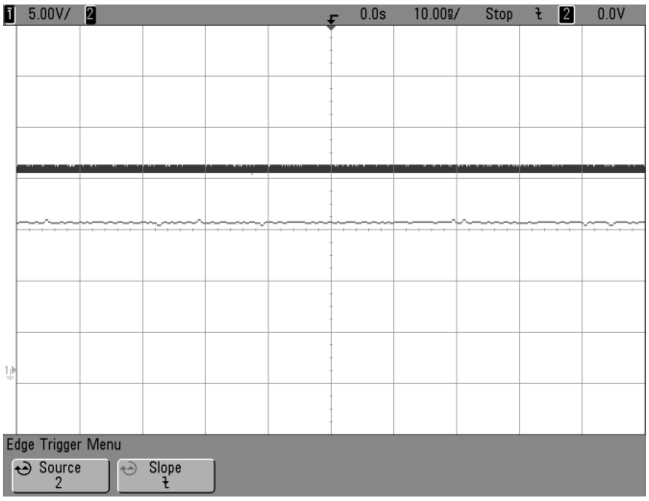

Fig.10. Motor Output voltage and Speed (CH1: output capacitor voltage [volt. scale: 5 V/DIV.]. CH2: Speed in voltage [volt.scale: 5 V/DIV.]

7. CONCLUSION

The Bridgeless buck converter have been modeled and simulated for estimating the performance for various load conditions. It has been found from the simulated results that the closed-loop controller provides better control strategies. It is concluded that the FLC-based circuit provides load-independent operation and better voltage regulation. A prototype full-bridge converter was designed, and the experiment results are compared with the simulation results. The experimental results closely agree with the simulation results. This modeling is expected to provide in-depth concepts to design engineers for various converter designs required for verity of application.

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