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Simulation of Interleaved Boost Converter Using Closed Loop Fuzzy Logic Controller

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Abstract

Interleaved power converters can be very beneficial for high performance electrical equipment applications. Reductions in size and electromagnetic emission along with an increase in efficiency, transient response, and reliability are among the many advantages to using such converters. Fuzzy Logic is a linguistic approach which emerges to design simple, complex and embedded systems with control inputs. A fuzzy logic uses linguistic variables which states IF A AND B THEN C" this rules is used for computation rather than a complex mathematical formula. In this paper, the interleaved boost converter (IBC) with closed loop fuzzy logic controller is simulated using MATLAB/SIMULINK software.

Keywords - Boost converter, interleaved (IBC), ripple, fuzzy logic controller.

Introduction

A simple boost convertor converts a low level DC voltage to high level DC voltage which reduces the ripple factors in both input and output circuit. To obtain higher efficiency the output current is splitting into two paths which reduce I2R losses and AC losses. IBC are employed in wide range of applications such as power factor correction circuits, fuel cell systems, and photovoltaic arrays etc [6]-[8]. In this paper, the design methodology of IBC has been elucidated. The computation of the inductance and the filter capacitance of the IBC have been done. The design of IBC has been carried out with the ultimate objective of reducing the ripple in the output voltage and the input current.

Fuzzy Logic is a linguistic approach which emerges to design simple, complex and embedded systems with control inputs. A fuzzy logic controller can be regarded as a real-time expert system that employs fuzzy logic to manipulate qualitative variables [1]. The design of a fuzzy system can be formulated as a search problem in high dimensional space, where each point represent a rule set, membership functions, and the corresponding system's behaviour. Linguistic variables, defined as variables whose values are sentences in a natural language (such as small and large), may be represented by fuzzy sets. Fuzzy logic controllers are an attractive choice when precise mathematical formulations are not possible.

The interleaved boost converter uses two boost converters which operate at 180 degrees out of phase. The inductor ripple cancellation occurs are 50% in duty cycle. The capacitor output is the sum of two diode current (I1+I2) which is less than the output dc current, which in turn reduces the ripple current if the output capacitor (IOUT), it also serves as a function of duty cycle. When the duty cycle tends to 0%, 50% and 100% the sum of the two diode currents also tends to dc output. Under any influence on optimum operating points, the capacitor output has to filter the inductor ripple currents.

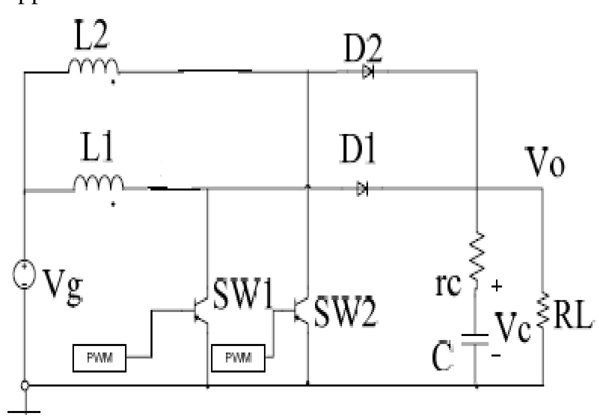

Fig. 1 A basic Two-phase interleaved boost converter

The interleaved boost converter which consists of two single-phase boost converters connected in parallel and then to a single output capacitor. The two PWM signal difference is 180 degree and each switch is controlled in the interleaving method. Since each inductor

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current magnitude is decreased according to one per phase, the inductor size and Inductance can be reduced and also the input current ripple is decreased.

The circuit of the interleaved boost converter is shown in Fig.2.The interleaved boost converter is popular as the configuration, minimizes the current ripple thereby reducing the size of the input filter. The input current also gets divided in the n-parallel paths and this leads to reduction in stresses also.

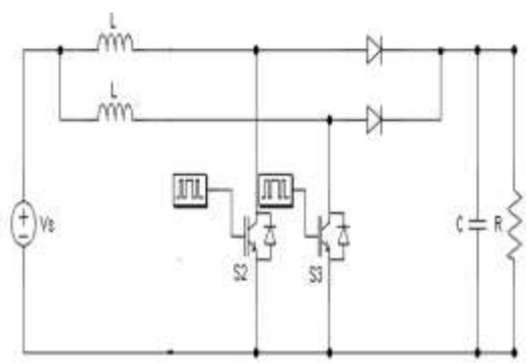

Fig. 2 circuit diagram of interleaved boost converter

The gating pulses of the IBC are shown in Fig.2. The IBC is made up of N-parallel boost converters [9]. The operation of IBC is similar to that of the conventional boost converter. The number of inductors and diodes is same as the number of phases. The switching frequency of the 3-phase IBC is identical but the gating pattern of each phase is shifted by an angle 360/N, n denotes the number of phases [10]. In case of 3-phase IBC, the angle is 120º. 3-phase IBC is mostly preferred as the current ripple can be reduced considerably. Interleaving technique reduces the Electromagnetic interference (EMI); therefore, the size of the EMI filter also gets reduced.

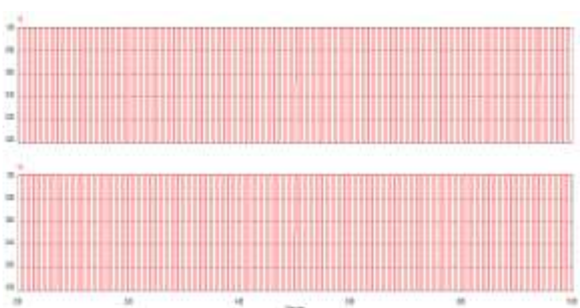

Fig. 3 gating pulses of interleaved boost converter

Operation of AN IBC with FLC

A. Interleaved Boost Converter

The interleaved boost converter is circuit of up level for voltage higher. It was simulating for design and analysis of inductance, capacitance, and resistance. The voltage control is important and need to study carefully. Firstly when the device S1 is turned ON, the current in the inductor iL1 increases linearly. During this period energy is stored in the inductor L1. When S1 is turned OFF, diode D1 conducts and the stored energy in the inductor ramps down with a slope based on the difference between the input and output voltage. The inductor starts to discharge and transfer the current via the diode to the load. After a half switching cycle of S1, S2 is also turned ON which completes the cycle of events. Because of both the power channels are combined at the capacitor output, the effective ripple frequency is twice of single phase boost convertor.

The gating pulses of the two devices are shifted by a phase difference of 360/n, where n is the number of parallel boost converters connected in parallel. For a two-phase interleaved boost converter n=2, which is 180 degrees and it is shown in Fig.2. The amplitude of the input current ripple is small. This advantage makes this topology very attractive for the renewable sources of energy.

B. Fuzzification

The first step in the design of a fuzzy logic controller is to define membership functions for the inputs. Five fuzzy levels or sets are chosen and defined by the following library of fuzzy-set values for the error *e* and change in error *ce*. Where NB negative big, NM negative medium, ZE zero equal, PM positive medium, PB positive big. The membership functions of input and output are trapezoidal function, as shown in Fig

C. Rule Base

Fuzzy control rules are obtained from the analysis of the system behaviour. In their formulation it must be considered that using different control laws depending on the operating conditions can greatly improve the converter performances in terms of dynamic response and robustness. The control rules that associate the fuzzy output to the fuzzy inputs are derived from general knowledge of the system behaviour. However, some of the control actions in the rule table are also developed using "trial and error" and from an "intuitive" feel of the process being controlled.

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Simulation and Result Analysis

The simulation is performed by MATLAB/Simulink software. The input voltage of the interleaved boost converter is 35V, and the output voltage V_o is 70V. The simulation circuit of the proposed converter is shown in Fig. 4. The load resistance R is 10Ω, L_1 is 3.3mH and L_2 is 3.3mH. The nominal duty cycle D is 45%. The output filter C is 2000µF.

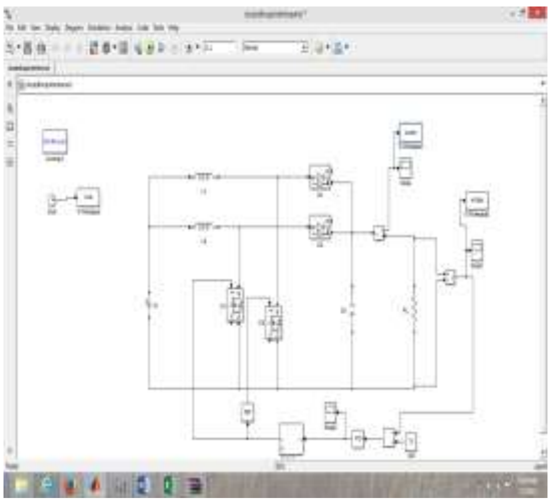

Fig. 4 simulation of IBC with closed loop control

The rules are formed according to the membership function based on Fuzzy logic and it is shown in Fig.5.

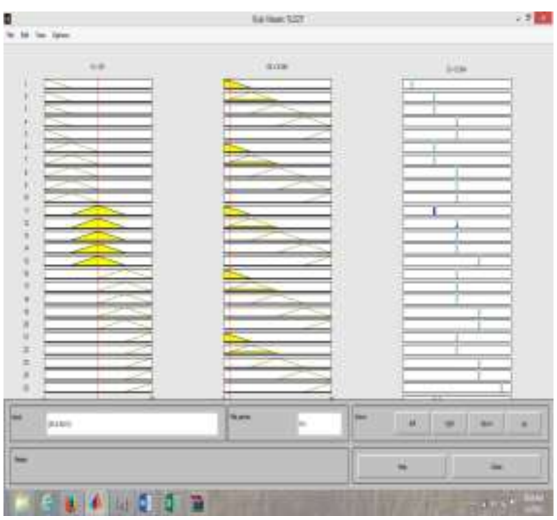

Fig. 5 membership function for input and output

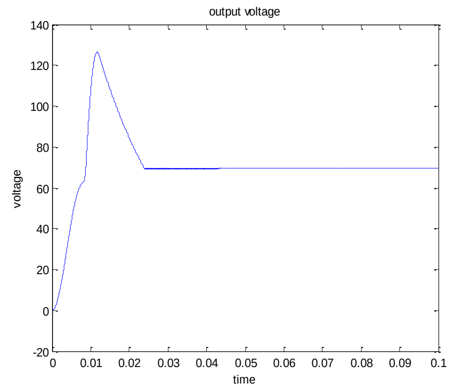

Fig. 6 output voltage of IBC without FLC

The output voltage and current waveforms are displayed in Fig. 6 and Fig .7 without the Fuzzy logic controller.

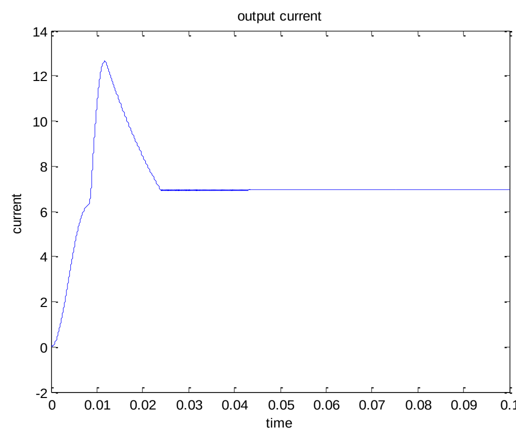

Fig. 7 output current of IBC without FLC

The interleaved boost converter with the switching frequency of 10 KHz and the simulation circuit is shown in Fig. 8 with the fuzzy logic controller.

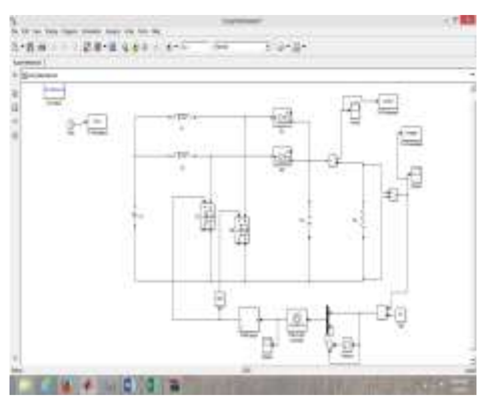

Fig. 8 simulation of IBC with FLC

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According to the membership function the rules are created and analysed with MATLAB/Fuzzy and it is shown in Fig. 9

When compare to interleaved boost converter without FLC, the interleaved boost converter with fuzzy logic control technique has less ripples in output current and more output voltage is obtained it is shown in Fig. 10 and Fig. 11.

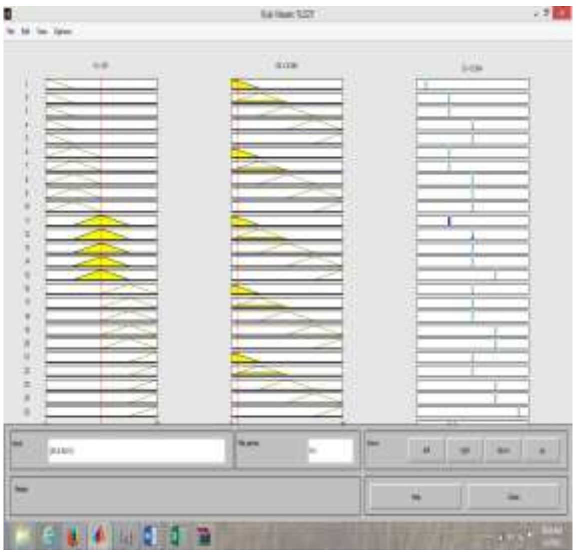

Fig. 9 membership function for input and output

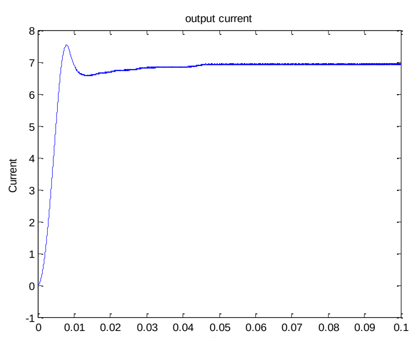

Fig. 10 output current of IBC with FLC

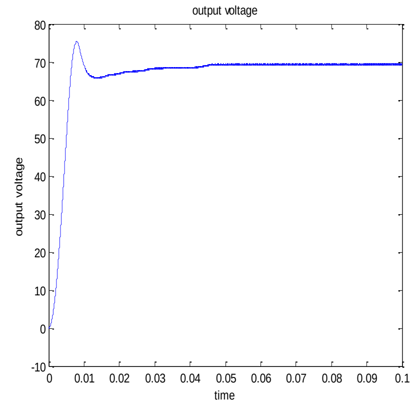

Fig. 11 output voltage of IBC with FLC

Conclusion

The design of fuzzy controllers does not require an exact mathematical model. Instead they are designed based on general knowledge of the plant. Fuzzy logic controller (FLC) is cheaper to develop, they cover a wider range of operating conditions, and they are more readily customizable in natural language terms. In this paper a fuzzy based interleaved boost converter mode is implemented in MATLAB/Simulink environment. From the output wave form, we can see that the proposed fuzzy logic controller is gives a smooth operation and high output voltage without ripples and also the settling time is reduced compare to conventional DC-DC converter without FLC.

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