A Novel Control Technique of Bridgeless Interleaved Boost Converter with Time Domain Parameters

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ABSTRACT

A Novel Control Technique and its Comparative analysis on four control techniques with Bridgeless interleaved Boost converter (BLIBC) is presented in this paper. The four control techniques are used namely, Proportional Integrator, Proportional Integral Derivative, Hysteresis Control and Fuzzy Logic Control. These four controls are compared with their time domain parameters. Peak time, settling time, steady state error & peak overshoot. Cascaded filter is used at the output to reduce the current ripple and power factor is improved. Simulation of Bridgeless interleaved boost converter is carried out using Simulink/MATLAB software of different control techniques and the results are represented. The hardware details related to the Bridgeless interleaved Boost converter and its wave form are also presented.

Keyword : - *Bridgeless interleaved boost converter, Time domain parameters and Control techniques.*

1. INTRODUCTION

The AC to DC Converter should be free from large voltage spikes and current harmonics. Continuous current are not present in the AC mains are due to the non-linearities of the rectification process. The harmonics present at the input current waveform reduces the distortion factor and also reduces the power factor. During the conversion from AC to DC the utility current can be formed using passive or active element these are the two approaches. In the first approach using the passive element such as inductor adds to the size and weight of which limits its choice for high power application. In the second approach Boost converter is used to shape the input current waveform. The size of the inductor is large for the conventional Power factor correction converter for high power application, Bridgeless interleaved boost converter for its small magnetic size , low input current ripple, and improved efficiency. The cascaded filter is used at the output to reduce the current ripple [11]. In this paper there are four different control techniques are used Proportional Controller, Proportional integral Derivative, Hysteresis Controller and Fuzzy logic control. These control techniques are compared with the time domain parameters and their results are presented in the simulink/MATLAB environment. The Hardware details of Bridgeless interleaved Boost converter is also reported in this paper

2. BRIDGELESS INTERLEAVED BOOST CONVERTER

2.1 PRINCIPLE

It is made of two bridgeless boost converters in Bridgeless Interleaved Boost converter which is operates in parallel. It yields the advantage of both bridgeless and interleaving of converter when compared to other conventional converters. It eliminates the need of input diode and it thereby holds the advantages of boost converter. It is used for high power applications which are greater than 1KW, where the power density and efficiency are critically required. The interleaving of boost converter made of two boost converters in parallel, operating at 180 degree shift out of phase. The current is the sum of the inductor currents also, these currents are drawn in 180 degree out of phase and they intend to cancel out each other, which decreases the high frequency input ripple current caused by the switching action of the boost converter. Conduction losses are reduced due to the paralleling action of the semiconductors. The use of cascaded filter at the output reduces the ripple content and improves the power factor [11]

For the topological analysis, the circuit is separated into two half cycles, Q1 and Q2 are turned on at one instant and Q3 and Q4 are turned on at the same (different) instant which is 180 degree out of phase with respect to the instance of Q1 and Q2. During the positive half cycle, Q1 and Q2 are turned ON and the current flows through L1, Q1, and Q2 & L2 and hence storing energy in L1 & L2. When Q1 and Q2 are turned off, the energy stored in L1 and L2 are passed as current through D1, load, body diode of Q2 and it is fed back to the mains. Similarly with 180 degree shift, Q3 & Q4 are turned ON and the energy is stored in L3 and L4 through Q3 & Q4 [1]

During the negative half cycle, Q4 and Q2 are turned ON, energy is stored in L2 and L1 for the first phase and L4 and L3 for the next phase and passes as current which flows through D2(D4) , load, Q1(Q3) and back to mains. A new loss as been introduced in the intrinsic body diodes of the MOSFET's but since input bridge rectifier are eliminated , there is some efficiency gain in the overall performance. The total loss for the proposed Bridgeless Interleaved boost converter is 40% lower than the conventional boost converter, 27% lower than the bridgeless boost and 32% lower than the interleaved boost converters. The bridge rectifier losses are so large that the BLIBC have least power loss when compared to other conventional converters.

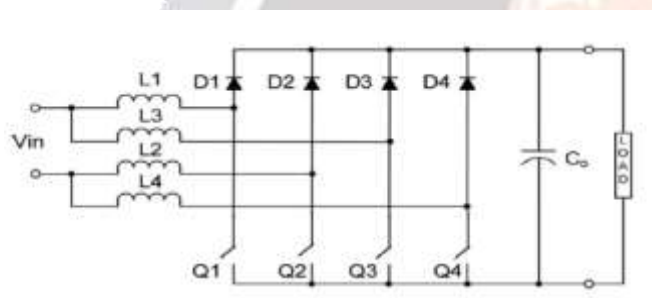

Figure 1: Bridgeless Interleaved Boost Converter

The BLIBC circuit diagram is shown in the figure 1, it is been proposed due its various applications and advantage in the improvement of the power factor and reduction of current ripple at the output.

2. CONTROL TECHNIQUES

2.1 PROPORTIONAL AND INTEGRAL CONTROLLER

The Proportional and integral controller does not predict the future errors. During the design of the PI controller for the DC to DC converter, a closed loop operation is performed. The open loop operation is insensitive to load and line disturbances. So this operation is ineffective. Therefore the closed loop operation is selected. PI Controller which is used in the Converter must contain minimum steady state error and less settling time.

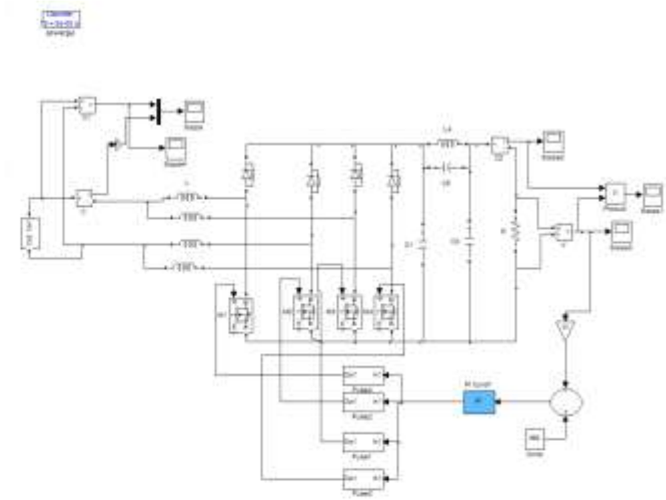

Figure 2: Simulation diagram of BIBC using PI Controller

The corresponding results are given as below,

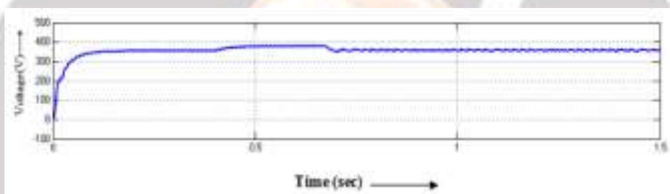

Figure 3: Simulation result of voltage versus time

We can see that the rise time to be 0.43s, settling time to be 0.63s, peak time to be 0.46s and steady state error 2.3. We can steady state error to be large. Settling time is large when compared to its rise and peak time.

Advantages:

- It increase the loop gain and makes the system less sensitive for the variation in parameters
- The steady state error is eliminated

Disadvantages:

- It has maximum settling time
- It cannot detect its future errors

2.2 PROPORTIONAL INTEGRAL AND DERIVATIVE

The Proportional controller (K_P) will reduce the rise time and the steady state error is not eliminated. The steady state error is eliminated using the integral controller (K_i) and it makes the transient response poor.

The PID controller transfer function is given as,

$$k_p + \frac{k_i}{s} + k_d s = \frac{k_d s^2 + k_p s + k_i}{s}$$

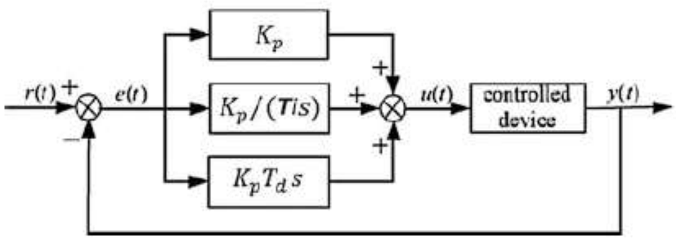

Figure 4: Schematic diagram of PID controller

The closed loop system is best suited for the PID Controller. The transfer function is given as,

$$k_p e + k_i \int e\,\mathrm{d}t + k_d \frac{\mathrm{d}e}{\mathrm{d}t}$$

The simulation diagram of Proportional integral and Derivative control is as shown in figure,

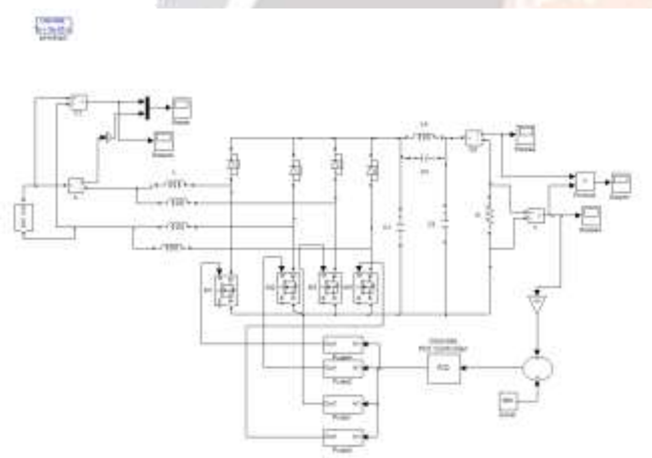

Figure 5: Simulation diagram of PID Controller

The corresponding MATLAB diagram is as shown in figure,

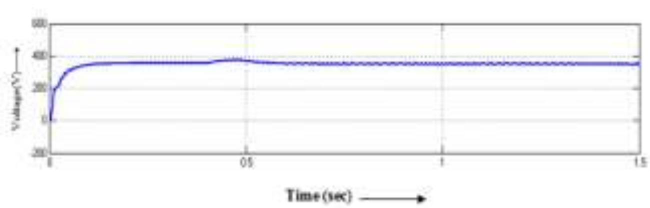

Figure 6: Simulation diagram of PID controller with Voltage versus Time in secs

Its Rise time (t_r) value is 0.42s, Settling time (t_s) value is 0.52s, Peak time (t_p) is 0.43 and the value of steady state error is 1.6. When we are comparing the values of the Proportional – Integral Controller with the Proportional- Integral- Derivative values we can see that, settling time has been reduced 0.8%, peak time is reduced by 0.3% and the steady state error has been reduced by 0.7%.

Advantages:

- Feasible
- Improves the dynamic response
- steady state error is reduced
- It can detect future errors and it is resolved

Disadvantages:

- It does not provide optimal control
- It has constant parameters and has no direct access over the process and the overall performance is problematic

2.3 HYSTERESIS CONTROL

The Hysteresis control Simulation diagram is given as follows,

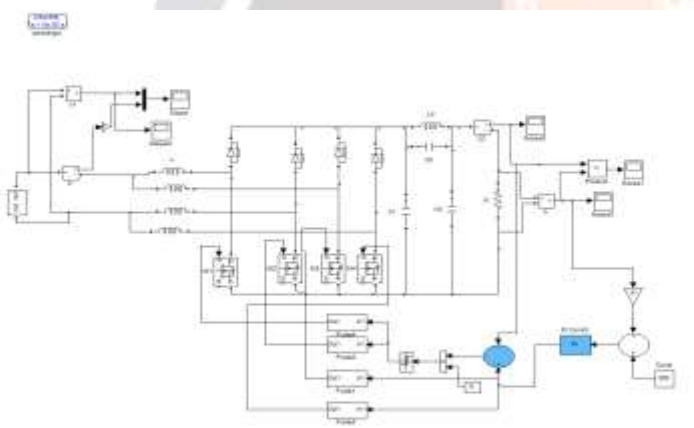

Figure 7: Simulation diagram of Hysteresis control

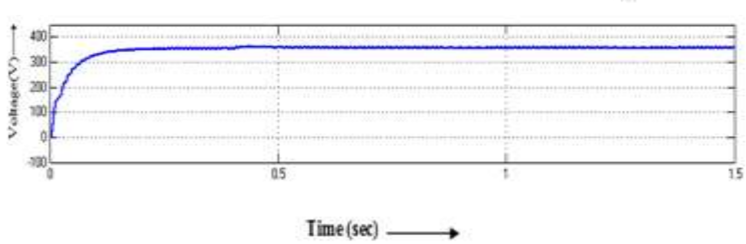

Figure 8: Simulation diagram of the Hysteresis Control with Voltage versus Time in secs

When compared with Proportional-Integral (PI) controller, the settling time and steady state error (e_{ss}) in Hysteresis control is much reduced. Where the settling time is 0.5s and the Steady state error is 0.9 are the values of the Hysteresis control. These values when compared to PID, the settling time and steady state error are reduced by 0.02% and steady state error is 0.7.

Advantages:

- To reduce the losses in low harmonics are sufficient
- Torque pulsation is less
- Less noise in motor
- Response is fast in order to provide high dynamic Performance

Disadvantages:

- Switching Frequency
- External Components and Operating conditions need to set the switching frequency
- There is no clock or synchronization signal setting switching frequency

2.4 FUZZY LOGIC CONTROL

The Fuzzy logic control simulation diagram is as shown in figure,

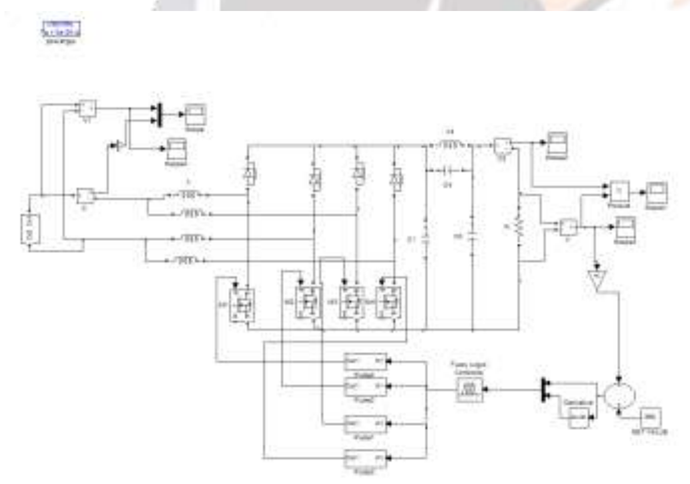

Figure 9: simulation diagram of Fuzzy logic control

The corresponding output is as shown in figure,

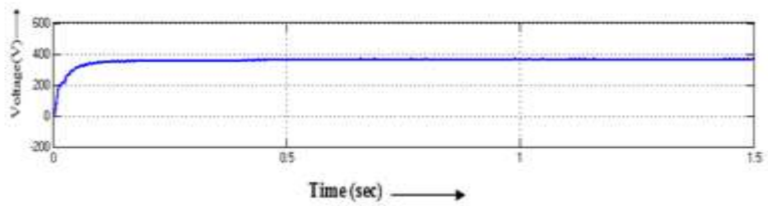

Figure 10: simulation diagram of fuzzy logic control with voltage versus time in secs

The Rise time (t_r) value is 0.21s, Settling time (t_s) value is 0.25s, Peak time (t_p) is 0.22 and steady state error (e_{ss}) is 0.08 are the values of Fuzzy logic control. When compared to Proportional-integral-derivative controller, FLC has less Settling time, Steady state error, Rise time and Peak time.

Advantages:

- Flexible, intuitive knowledge base design, Control and supervision speak and the same language.
- Convenient user interface, easier end – user interpretation when the final user is not a control engineer
- Easy consumption. Widely available toolboxes and dedicated integrated circuits.
- Learning, linear in parameter systems makes possible least squares, dead zone learning algorithms and other results from adaptive control

Disadvantages:

- Experimental, Manual tuning in large scale industrial applications. Time consuming returning even if applied to a similar plant in other location

3 TIME DOMAIN PARAMETERS

The time domain parameters for the proposed topology is described as below,

1. Rise Time (t_s):

It is the time taken by the response to rise from 0 to 100% for the very first time.

2. Peak Time (t_p):

It is the time response to reach the peak value for the very first time.

3. Settling time (t_s):

It is the time taken by the response to reach and stay within a specified error. It is represented as % of final value.

4. Steady state error (e_{ss}):

It is the difference between the set value and the actual value.

The comparative results of the four different control techniques are summarized as follows from the results of the closed loop simulation and there corresponding waveform are shown in Table 1:

Table 1: Comparative results of control techniques used for BIBC with their time domain parameters:

Control	**Rise**	**Peak**	**Settling**	**Steady**

Technique	time (t_s) secs	time (t_p) secs	time (ts) secs	state error (e_{ss})
Proportional-Integrator Control	0.43	0.46	0.68	2.3
Proportional-Integrator-Derivative Control	0.42	0.43	0.52	1.6
Hysteresis Control	0.40	0.41	0.5	0.9
Fuzzy Logic Control	0.21	0.22	0.25	0.08

The comparison of the four different control techniques are summarized in table 1

4. CONCLUSIONS

We have discussed about the Bridgeless Interleaved Boost converter and its control techniques which are compared based on the time domain parameters in this paper. The comparison results for the four different types of the control are summarized. Simulation of different control techniques are carried out in MATLAB software. It is found that Fuzzy Logic Control has the minimum settling time, rise time, steady state error and the peak time when it is compared with other three control techniques. Fuzzy logic Control has the best dynamic response. Hence it is the best control technique for the DC-DC Converters.

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