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Comparative Study between PI and Fuzzy Logic Controller Based Power Factor Correction and THD Minimization using Interleaved Boost Converter

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ABSTRACT
Boost converter is most widely used as active power factor due to its ability of drawing continuous input current which can be manipulated by current mode control technique. However boost power factor corrector suffers from the problem of presence of ripples in the input current. This problem can be overcome by using interleaved boost converter. In this paper power factor correction and THD minimization is performed by interleaved boost converter controlled by average current mode control by using two different controllers. Here at first simulation is performed by PI controller and thereafter fuzzy controller is used and comparison of performance of two controllers is discussed.
Keywords – Interleaved boost converter, Fuzzy controller, PI controller, Power Factor, THD.

I. INTRODUCTION

Single phase diode ac to dc converters with filter capacitor are being used as front-end rectifiers in variety of applications. But in order to achieve high power factor and low THD, use of power factor corrector is required. Boost converters are mostly preferred as active power factor corrector [1] in this respect, due to its capability of drawing continuous input current. This continuous input current can be controlled by various current mode control techniques [2]. Among all current mode control techniques average current mode control [3] provides the best result due to its advantages like constant switching frequency, good input current waveform etc.

Though boost converters are very popular as power factor corrector, but it suffers from the problem of presence of ripples in the input current and also it cannot be recommended for high power as the switch is subjected to high current levels. In order to overcome the drawbacks of boost converter, interleaved boost converter [4], [5] is used.

In this paper two phase interleaved boost converter [6], [7] is used for power factor correction and THD minimization. The two phases of interleaved boost converter are phase displaced by 180˚ to minimize the ripple of input current.

Now here for control purpose two different controllers PI and fuzzy logic controller are used. Though PI controllers are most popular and widely used, but fuzzy logic controller has emerged as most intelligent controller which is much closer in spirit to human thinking. So the fuzzy logic controller is supposed to give the better result than PI controller [8]. This paper shows simulation of average current controlled two phase interleaved boost converter using PI and fuzzy logic controller. All the simulation is carried out in MATLAB-Simulink.

II. FUZZY LOGIC CONTROL

Fuzzy logic controller is based on the mathematical tool which is used to represent human language and human knowledge, and was first introduced by Prof. Lotfi Zadeh. The point of fuzzy logic controller is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements which is called fuzzy rules. So fuzzy logic controller uses linguistic rules developed depending on human expert knowledge. Hence fuzzy logic control provides faster and smoother response than the conventional controllers and control complexity is less.

III. PROPOSED SYSTEM

The proposed system which is used for power factor correction and THD minimization by average current controlled interleaved boost converter using two different controllers PI and Fuzzy logic controller is shown in Fig.1.
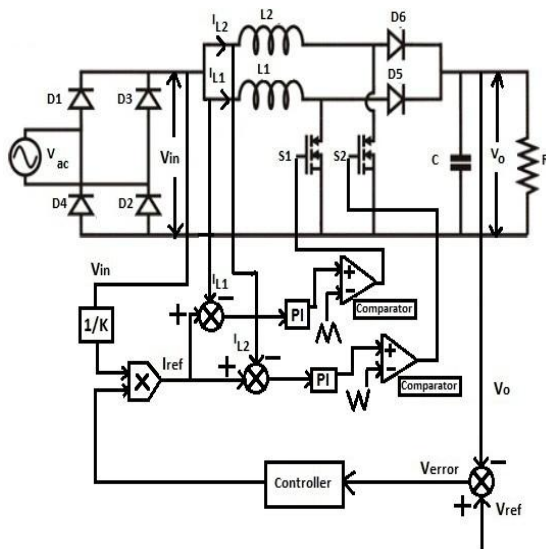

Fig.1 Block diagram of the proposed system.

Interleaving technique consists of a phase shifting of the control signals of cells in parallel operating at the same switching frequency. Here for the power factor correction, a two phase interleaved boost converter is used. The continuous current drawn by the interleaved boost converter, is controlled using average current mode control. For ripple reduction the two phases of interleaved boost converter operate in 180° out of phase.

When switch S1 is on and switch S2 is off:

$$\frac{dI_{L1}}{dt} = \frac{V_{in}}{L1} \tag{1}$$

$$\frac{dI_{L2}}{dt} = \frac{V_o - V_{in}}{L2} \tag{2}$$

When switch S1 is off and switch S2 is on:

$$\frac{dI_{L1}}{dt} = \frac{V_o - V_{in}}{L1} \tag{3}$$

$$\frac{dI_{L2}}{dt} = \frac{V_{in}}{L2} \tag{4}$$

The two inductor currents will be out of phase and cancel out the ripple of each other if:

$$\frac{V_{in}}{L1} = \frac{V_o - V_{in}}{L2} \tag{5}$$

$$\frac{V_o - V_{in}}{L1} = \frac{V_{in}}{L2} \tag{6}$$

The above two equations i.e. equation (5) and equation (6) will be satisfied if and only if L1 = L2

and $V_o = 2V_{in}$.

The average current mode control uses voltage control loop and current control loops. To generate the reference currents for two inductor currents, the error voltage obtained by comparing output voltage and reference voltage, is passed through a controller and the output is multiplied with scaled rectified voltage. Then the comparison between inductor current and reference current is passed through PI controller. Comparing the output with sawtooth wave the PWM signal for switch is generated. To obtain phase shift of 180°, two saw tooth waves are phase displaced by 180°.

In this paper two controllers PI and Fuzzy logic controller are used as voltage loop controller.

IV. FUZZY ALGORITHM

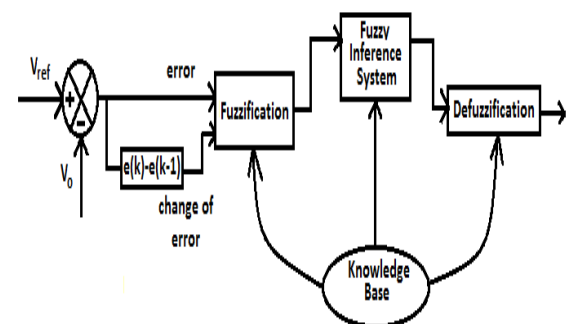The basic block diagram of fuzzy logic controller is shown in Fig.2.

Fig.2 Block diagram of fuzzy logic controller

The error voltage obtained by comparing output voltage and reference voltage, and the change of error are first applied at the input of fuzzy logic controller. Now this obtained input data is converted to suitable linguistic terms through fuzzification. A knowledge base is provided which contains all the necessary definitions of all linguistic variables and the control rule set. Fuzzy inference system provides the more weighted output depending on the control rules i.e. the if-then statements provided in the knowledge base. Now the defuzzification involves converting the output term into a crisp value such that it is compatible with all systems.

To convert the numerical inputs into linguistic terms five fuzzy levels are chosen. The five fuzzy levels used for inputs are NB (Negative Big), NS (Negative Small), ZE (Zero), PS (Positive Small), and PB (Positive Big). The five fuzzy levels used for output are PVS (Positive Very Small), PS (Positive Small), M (Medium), PB (Positive Big), and PVB (Positive Very Big).

The rule base of fuzzy logic control is based on the theory that large errors need coarse control, which requires coarse input or output variables and small errors need fine control which requires fine input or output variables. The control rule base for fuzzy logic controller is given in table 1.

Table 1: Control Rule Base

Error/Change of Error	NB	NS	ZE	PS	PB
NB	PVS	PVS	PVS	PS	M
NS	PVS	PVS	PS	M	PB
ZE	PVS	PS	M	PB	PVB
PS	PS	M	PB	PVB	PVB
PB	M	PB	PVB	PVB	PVB

V. SIMULATION RESULT AND DISCUSSION

For comparison between PI and Fuzzy logic controller, simulation of average current controlled interleaved boost converter using PI and Fuzzy logic controller is done, in MATLAB-Simulink.

The reference output voltage is taken 400v and the output resistance is 160 ohm. So the system has output power of 1KW. Now first the output voltage curve using PI controller is shown in Fig.3.
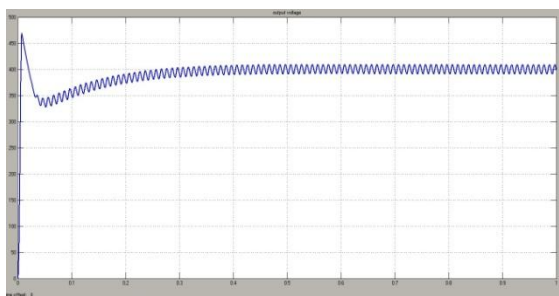

Fig.3 Output voltage using PI controller.

It can be seen from Fig.3 that output voltage is maintained at 400v. The rise time is 0.27s and the overshoot is 17.5%. Now the output voltage curve using Fuzzy logic controller is shown in Fig.4.
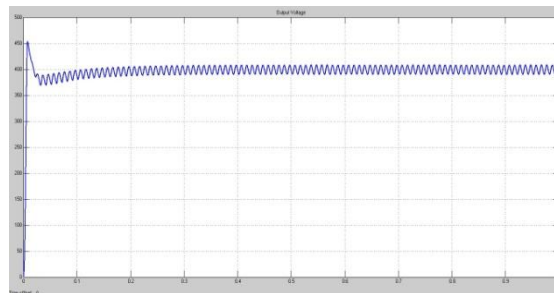

Fig.4 Output voltage using Fuzzy logic controller.

Here also we can see that output voltage is 400v but here response is much faster. Here rise time is 0.125s and the overshoot is 13.5%.

Now the input voltage and input current waveform for both PI and Fuzzy logic controller is shown in Fig.5 and Fig.6 respectively.
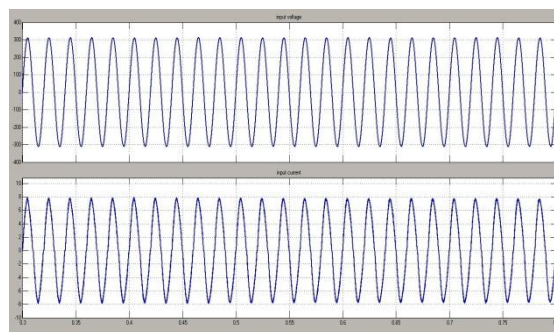

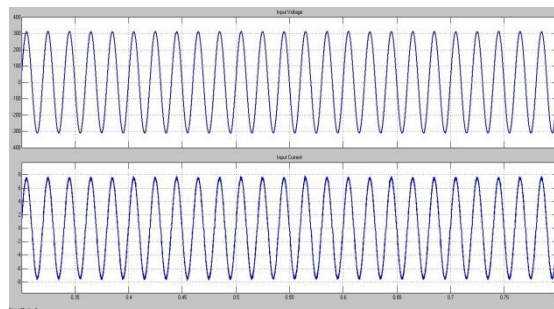Fig.5 Input voltage and input current waveform using PI controller.

Fig.6 Input voltage and input current waveform using Fuzzy logic controller.

From Fig.5 and Fig.6 we can see that for both PI and Fuzzy logic controller the input current is sinusoidal as the input voltage waveform. Now the power factor can be calculated for PI and Fuzzy logic controller from the Active and Reactive power waveform shown in Fig.7 and Fig.8 respectively.
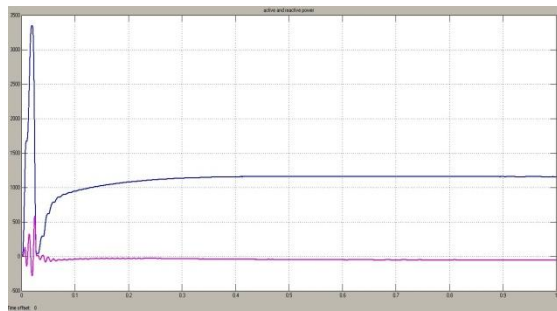
Fig.7 Active and Reactive power waveform using PI controller.

We can see from Fig.7 that active power is 1155W and reactive power is -55VAr. So the power factor for PI controller is 0.9988.
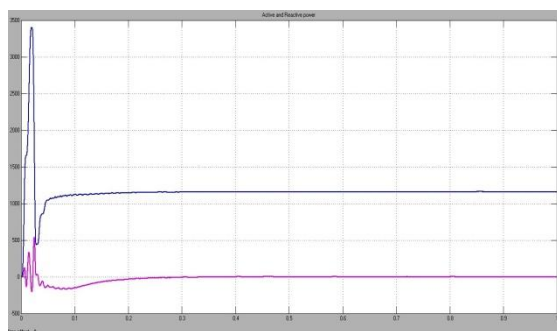

Fig.8 Active and Reactive power waveform using Fuzzy logic controller.

In case of Fuzzy logic controller the active power is 1155W and reactive power is -5VAr. So power factor for fuzzy logic controller is 0.9999.

Now the THD of input current for both PI and Fuzzy logic controller is shown in Fig.9 and Fig.10 respectively.
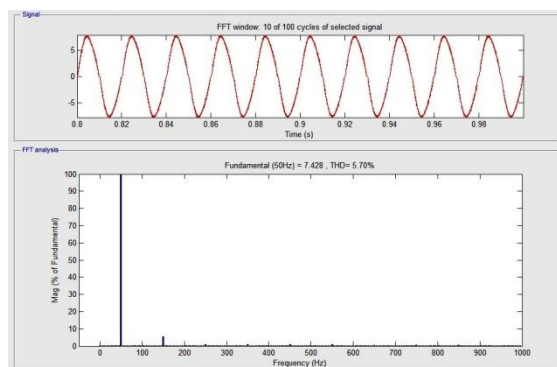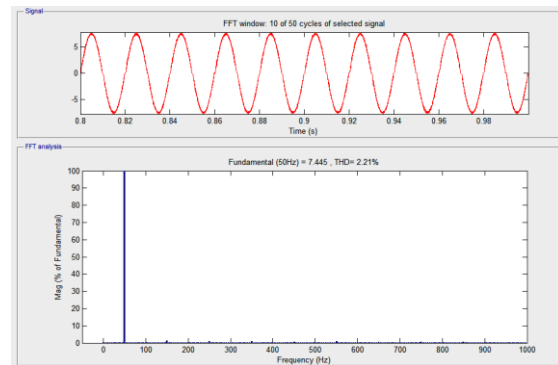

Fig.9 THD using PI controller.

Fig.10 THD using Fuzzy logic controller.

From fig.9 and Fig.10 it can be seen that using PI controller THD is 5.70% and using Fuzzy logic controller THD is 2.21%.

The comparison of performance of PI and Fuzzy logic controller is shown in Table2.

Table 2: Comparison of performance of PI and Fuzzy logic Controller

Type of controller	Settling Time	Maximum Overshoot	Power Factor	THD %
PI	0.27s	17.5%	0.9988	5.70
Fuzzy	0.125s	13.5%	0.9999	2.21

So from above table it is evident that use of fuzzy logic controller provides better control and much better result than the conventional PI controller.

VI. CONCLUSION

Now days power factor correction techniques are gaining increasing attention. In this paper power factor correction and THD minimization is done by average current controlled interleaved boost converter using PI and Fuzzy logic controller. In both cases power factor is almost unity and THD is considerably minimized. From the comparison of performance of PI and Fuzzy logic controller it is also evident that fuzzy logic controller provides much better result and faster and smoother response than the conventional PI controller.

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