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PI and Fuzzy controlled Two-Phase Interleaved PFC Boost Converter

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Abstract: *The applications of power electronic converters has increased widely in different sectors like industrial, commercial, residential, aerospace due to rapid development in power semiconductor devices. Due to presence of power semiconductor devices the current drawn from line is distorted resulting in a high Total Harmonic Distortion (THD) and low Power Factor (PF). So there is a need to improve Power Factor and reduce line current harmonics. This paper aims to develop a circuit for PFC using a pi and fuzzy controlled two phase interleaved boost converter. The PFC strategy uses the interleaving scheme with pi and fuzzy controllers for reducing input current harmonics. The developed circuit model is simulated by using matlab software. The simulation result will show that there is a significant decrease in THD and improvement in Power Factor.*
Keywords: *PFC Boost converter, interleaving scheme, pi and fuzzy system.*

I. Introduction

Power factor is defined as the cosine of angle between voltage and current in an AC circuits or the ratio of active power to apparent power to be 100%. In an AC circuits, there is generally a phase difference ϕ between voltage and current. The term cos ϕ is called power factor. Power factor plays an importance role in AC circuits since power consumed depends up on this factor. Lower the power factor, higher the load current and vice-versa. A power factor less than unity results various disadvantages like large copper losses, poor voltage regulation, larger kVA rating etc. So due to these effects there is a need to improve power factor. Two types PFC circuits are present, they are active PFC, and passive PFC. Among these two active PFC is preferred due to its small form factor and higher power factor. Higher power factor means the PFC circuit employed will shapes out the input current waveform in phase with the input voltage waveform.

Passive power factor correction

This type of control technique uses elements like capacitor and inductor based on our requirement. These components will act as filters which allow currents to pass through them only at frequency 50 or 60 Hz. Then the filters will reduce the harmonic content in the current which is flowing through the filter which makes non linear load look likes a linear load. So by using these filter the power factor can brought to unity. Even though power factor is corrected there may be some limitations in the passive PFC they are filter requires large value high current inductors which are bulky and expensive and inefficient since it works at line frequency.

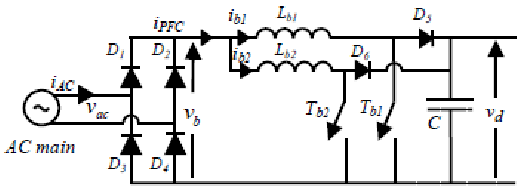
Active power factor correction

To overcome the limitations in passive PFC the active PFC technique is proposed. The most effective way to correct power factor of electronic supplies is active approach. The active PFC consists of a power electronic system which changes the wave shape of current drawn by load to improve power factor. There are various types of systems are present for PFC they are boost, buck, buck-boost converters. Consider a simple operation of active PFC here; place a boost converter between the bridge rectifier and the main input capacitor. The operation of converter is to maintain a constant DC output bus voltage and draws a current in phase with and at the same frequency as the line voltage. A control circuit is present in this system which is used to measure the input current and comparing with the input voltage waveform and adjusts the boost converter to produce an input current waveform of same shape. Boost converters also have a limitation that is even though it has the capability of PFC it suffers with a problem of reducing ripples in the input current. It also has a limitation that it is not recommended for high power because the switch is subjected to higher current levels. So to overcome the disadvantage of boost converter, interleaved boost converter is proposed.

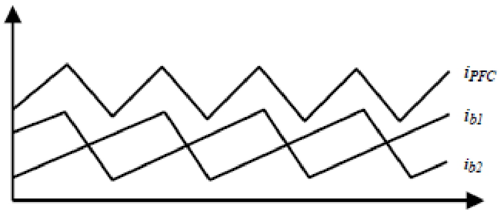
Pi and fuzzy controllers are used for reducing the total harmonic distortion. Pi controller is based on a précised mathematical model of the system otherwise pi controller operation is not efficient and accurate. This controller also fails to perform accurately under variable conditions. So to overcome the disadvantage of pi controller an intelligent control technique is introduced nothing but a fuzzy system. Fuzzy system works on the basis of linguistic variables and makes a intelligent decisions to reduce the errors. It has superior characteristics than pi controller in reducing harmonics. Thus fuzzy system gives a better performance in reducing the total harmonic distortion (THD).

II. Proposed System

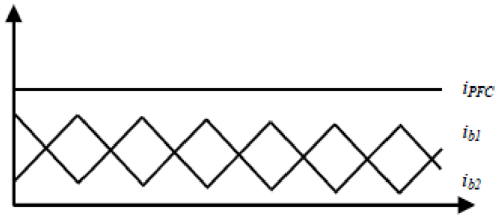
A) Interleaved boost converter



(a)



(b)



(c)

Figure.1 (a) Two-phase interleaved PFC boost converter (b) waveforms of two phase interleaved PFC boost converter under normal operating conditions (c) waveforms of two phase interleaved PFC boost converter using a voltage tolerance phase shifting technique

The basic diagram of interleaved PFC boost converter is shown above. Two boost converters are connected in parallel with 180 degree phase shift present between them. The operation of proposed converter is when switch Tb1 is on then switch Tb2 is off and vice versa. When switch Tb1 is on then the current flowing through inductor Lb1, d5 to the output, when switch Tb2 is on then the current starts flowing through Lb2, D6 to the output side. So there is a continuous path for the current to flow continuously to the output. Consider waveforms shown ib1 is the current during switch Tb1 on and ib2 is the current during switch Tb2 is on, the resultant of both the currents is represented as iPFC. In single boost converter the continuous operation of converter results in hard switching of diode which results in reduced power conversion efficiency. This drawback can be overcome by using interleaved boost converter. Consider waveform (a) under normal operating conditions even though the current is continuous the current is not a pure dc some ripple content is present in the current. The reason for having ripple current is the parallel converters are not exactly 180 degrees out of phase, the angle may lead or lag i.e. angle may be greater or less than 180 degrees. so there is a presence of ripple content in current. This disadvantage can be overcome by using a variation Tolerant Phase Shifting Technique.

Variation tolerant phase shifting technique

The proposed technique is used for maintaining exact 180 degree phase shift between two converters. The technique uses two zero crossing detectors which are used to measure the zero crossing of voltage at the inductors of parallel converters. Then the two zero crossing detectors are compared, if there is any error present it states that the converters are not exactly 180 degrees out of phase there is change in angle so to maintain the angle exact 180 degrees the error value from comparison of two detectors is added to the change in degree of phase shift between two converters then we get exactly 180 degree phase shift between them. The resultant output current which is a pure dc shown in waveform (b).

B) Control circuit

The control scheme adopted in this proposed system can be implemented easily and it's very simple. Consider the operation here, Vo* is the reference voltage that is expected at the output of the interleaved boost converter. Vo is the actual output of the proposed converter. The two voltages are compared by comparator then the error value is given to the voltage controller. The voltage controller nothing but a pi controller process the error signal and generates appropriate current signal Is. Unit sinusoidal template is obtained by using a phase locked loop. Then the sinusoidal template is multiplied with generated signal from the controller, we get output as Is sinwt to produce reference signal Is*. The actual current signal is taken from converter i.e. Ic. Absolute value is taken from reference signal Is* by using absolute circuit we get reference signal as Ic*. Then two currents Ic &Ic* are compared then error value is given to current controller to produce proper gating signal. The current controller used here is a hysteresis controller which is shown in fig.2.

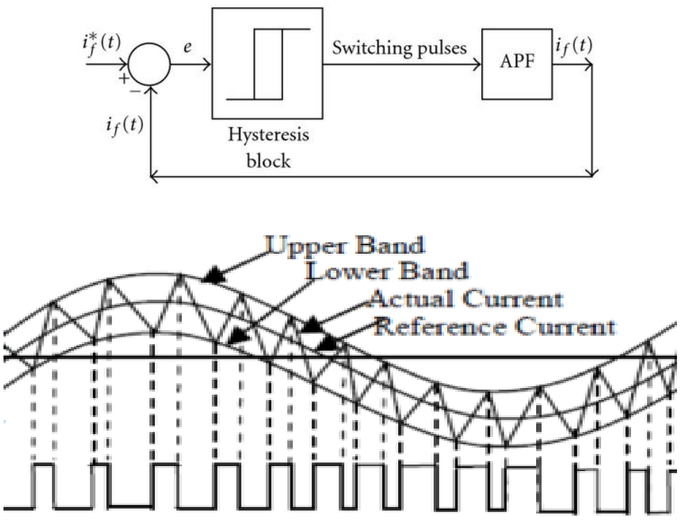


Figure .2 hysteresis controller

Consider the working principle of hysteresis control here, the lower and upper hysteresis band in controller is created by adding and subtracting a band value 'h' with the reference current which is shown in fig . the aim of this controller is to maintain the inductor current within the hysteresis band. This can be obtained as when the actual current tries to go above upper limit the pulse is removed to the switch then current is forced to fall and flows through the load. When the current goes below the lower band then the pulse is given to the switch then current is forced to rise. So in this way power switch can be operated to track the reference current and the resultant current drawn by the loads will be nearly sinusoidal and the harmonic content in current will be reduced and maintains low total harmonic distortion value(THD), then the power factor is improved.

c) Fuzzy system

The basic block diagram of fuzzy logic controller is shown in fig.3

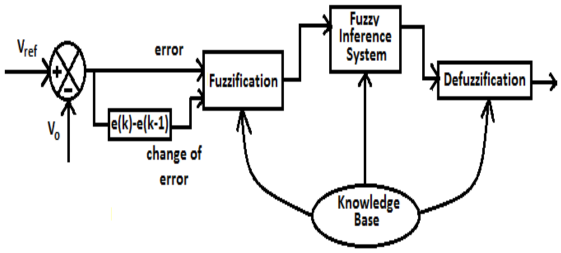


Fig.3 block diagram of fuzzy logic controller

Fuzzy is a rule based system. The operation of fuzzy is, the error voltage obtained by comparing the reference voltage and output voltage and change of error are applied to the input of fuzzy logic controller. The data given to fuzzy system is converted in to linguistic variables through fuzzification process. A knowledge base is available which is provided with necessary definitions of all linguistic variables and controller rule set. Fuzzy inference system takes the input from fuzzification block and provides more weighted output depending

on control rules i.e. if then statements given by the knowledge base. Now the output is given to defuzzification block which converts output term in to crisp value such that it is compatible with all systems.
Fuzzy logic uses linguistic variables instead of numerical variables. In a control system, error between reference signal and output signal can be assigned as Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (ZE), Positive small (PS), Positive Medium (PM), Positive Big (PB). To convert numerical inputs to linguistic variables fuzzy system uses above mentioned fuzzy levels.
The control rule base for fuzzy logic controller is given in the table 1.

ce / e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NB	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table 1: control rule base

III. Matlab/Simulink Modelling And Simulation Results

The Simulink model of two phase interleaved power factor correction boost converter using fuzzy and pi controller is shown in fig.4

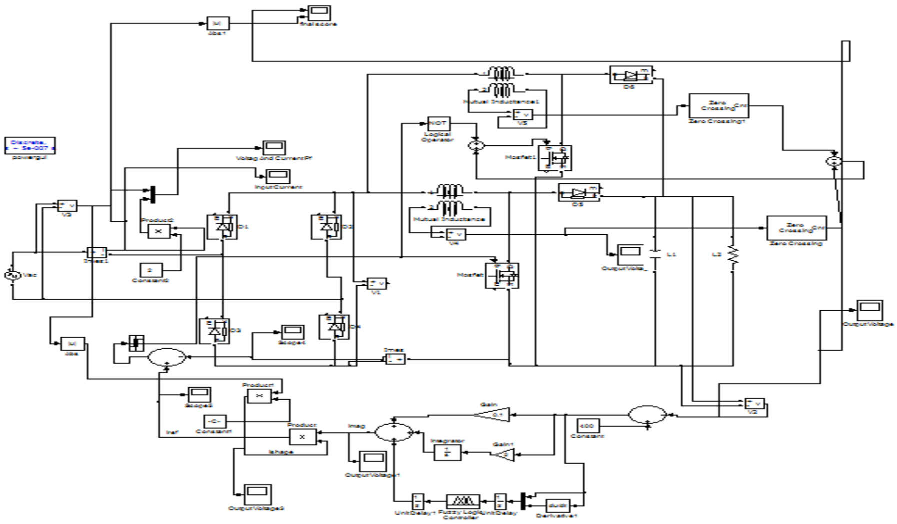


Figure.4 matlab/Simulink model of proposed two phase interleaved power factor correction boost converter using fuzzy and pi controller

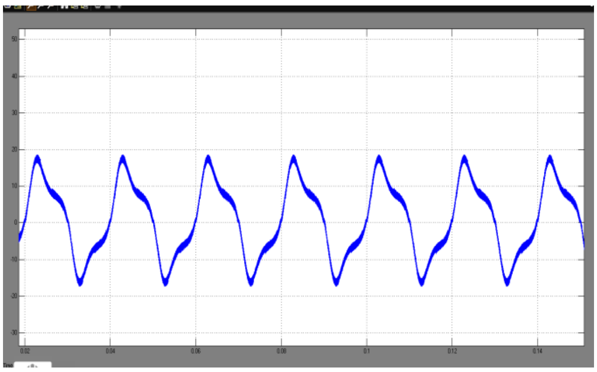


Figure.5 Input current wave form without any controller

Fig (5) shows the input side current without using any controllers the input current waveform is non-sinusoidal and ripple content present is more.

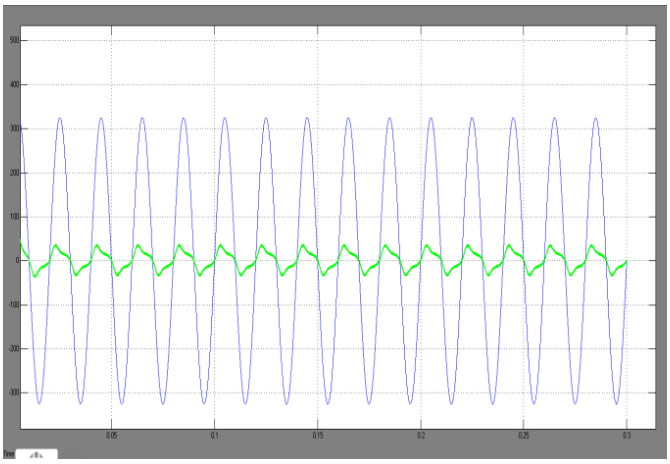


Figure.6 Input current and voltage waveform without any controller

Fig (6) shows the voltage and current waveforms without any controllers

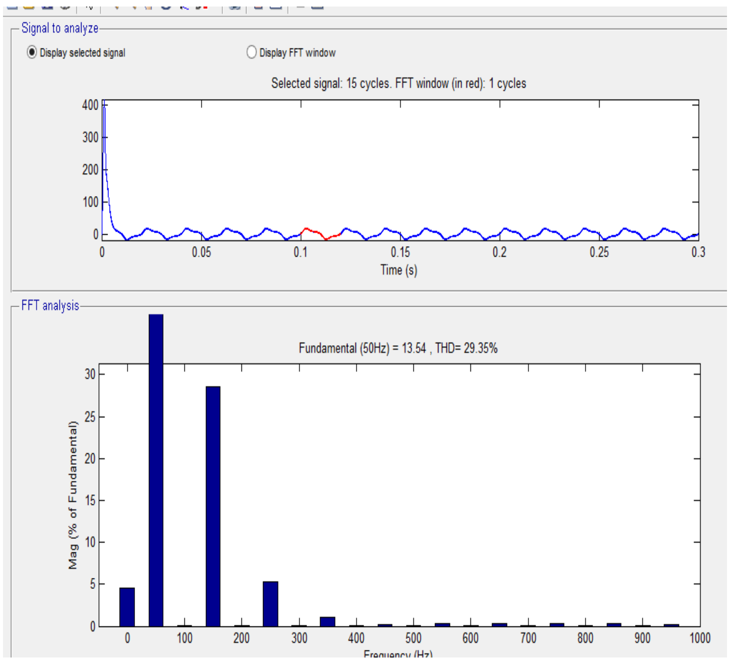


Figure.7 THD analysis of source current

Fig (7) shows the FFT analysis of source current without any controller; we get THD as 29.36%

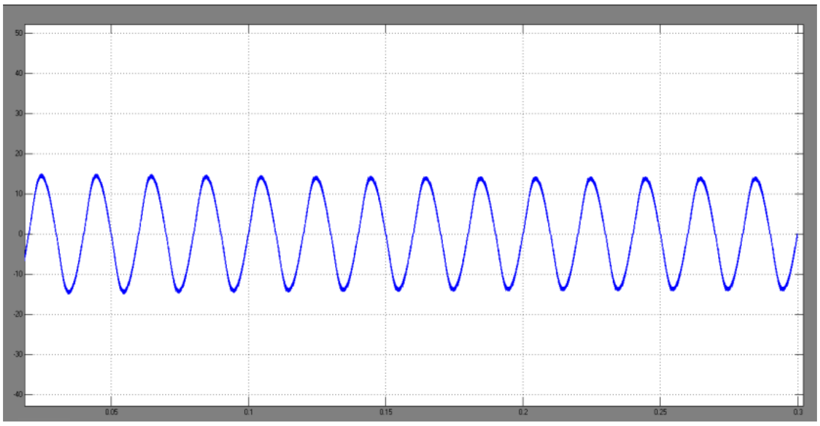


Figure .8 Input current waveform

Fig (8) shows the input side current using pi and fuzzy controller's results in sinusoidal shape

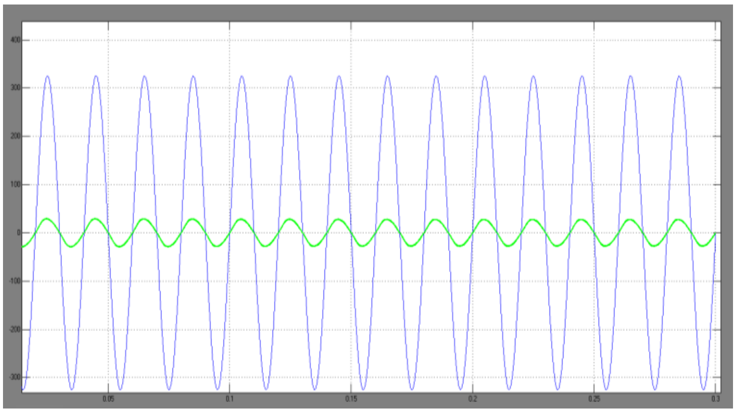


Figure.9 Input current and voltage waveform

Fig(9) shows the voltage and current waveforms using pi and fuzzy controller's results in maintaining the shape of current same as the voltage waveform maintaining power factor

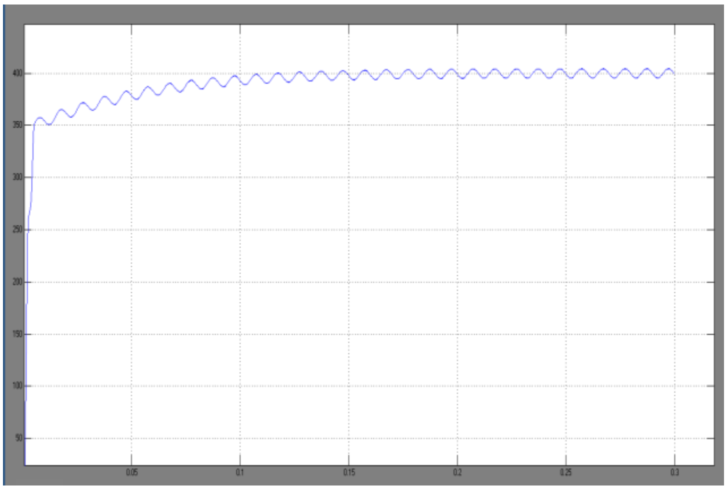


Figure.10 output voltage waveform of proposed system

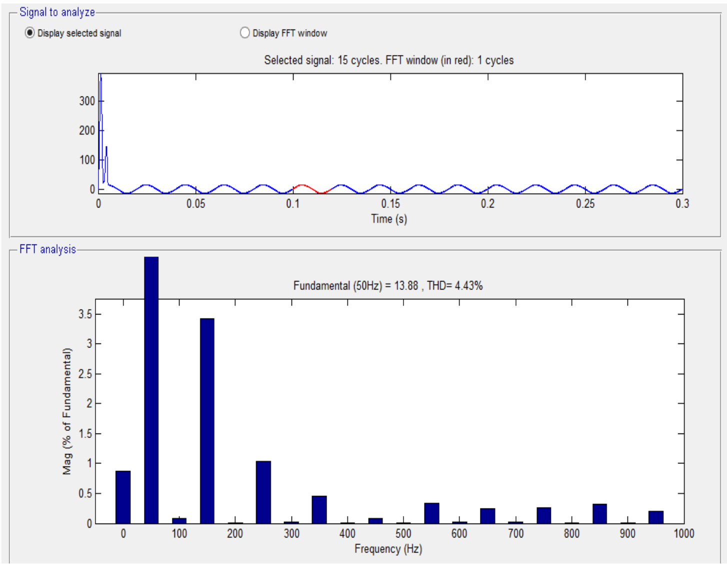


Figure.11 THD analysis of source current

Fig (11) shows the FFT analysis of source current using fuzzy and pi controllers we get THD as 4.43%. This shows that there is significant decrease in THD when compared to a system without any controllers.

IV. Conclusion

A two phase interleaved PFC converter with pi and fuzzy controllers has been developed and simulated by using matlab software. The results of proposed converter shows there is significant decrease in the THD value and power factor correction is done. There is a significant reduction in ripples present in the input current and maintains the input current in phase with the input voltage when compared with system without any controllers.

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