Fuzzy peak current controlled integrated PFC converter with slope compensation

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Abstract

This propounded a novel method of design and implementation of a fuzzy peak current mode (PCM) controlled Buck Integrated Power Factor Correction (PFC) Converter with compensation ramp. It derives its advantages through low buck capacitor voltage and single control switch, which leads to reduced complex control and price. Sub-harmonic oscillations generates in peak current controller can be nullified by using ramp signal, there by improves the overall performance of the converter. The fuzzy controller (FLC) robust and effective than conventional linear controllers like P, PI, PID, hence in this work a (90 – 265V), 50Hz AC, 48V DC and 100 kHz frequency converter is implemented in MATLAB/Simulink software and results are presented. Results show that converter meets international regularity commission regulations.

Keywords: Fuzzy Controller; Peak Current Control; Integrated Converter; Power Factor; Slope Compensation.

1. Introduction

Growing use of AC/DC power converters in industrial, transport, utility systems and home appliances introduces harmonic currents on low voltage AC public mains networks. To minimize these harmonics and to meet IEC 61000-3-2 and other international regulations, the traditional method of using passive components network is not suitable for medium and high power levels due to increase in component size and lower efficiency [1]. Another method proposed in the past literature was active power factor correction technique [2]. The active power factor correction done with the help of simple single converter module is referred as single stage active power factor correction, but high current stress in switch and EMI problems makes it unattractive [3]. The next approach is two stage approaches, in which two separate converters are connected in cascade and out of two converters, one converter acts like a power factor correction converter and another acts as a voltage regulator [4]. These two converters are controlled independently with two different controllers to realize the goal. Therefore it is expensive and more suitable for high power applications. This paper proposes an integration of converters approach which has the features of both single converter approach and two stage approaches.

In recent year, an Artificial Intelligent technique like Fuzzy logic is applied to improve the gains of the controllers to give better performance. Fuzzy control system uses the knowledge, experience and intelligence of a human expert to make decisions about the behavior of the system [5], [6], [7].

In this paper, analysis and design fuzzy PCM controlled buck integrated flyback converter with compensating ramp is accomplished for Class-C&D appliances to reach nearly unity PF and regulated output.

2. Integrated PFC converter

In this paper by using features of buck and flyback converter an integrated PFC converter is considered which integrated buck flyback converter, shown in Fig.1 is. Buck Converter consists of Lb, Dc, Da, SW1, Vp and Flyback Converter consists of Cb, SW1, 1:m, Db, Da, Dd, Co. SW1 shares both converters.

![Fig. 1: Integrated PFC Converter.](image)

Operation of this converter can be understood in 4 stages, During stage 1, SW1 is closed; inductor Lb and Lf gets charged up from source current in the primary, while in secondary diode Dd is reverse biased. Therefore by flyback concept secondary inductor gets charged. Output capacitor (Co) discharges through the load. During stage 2, SW1 is opened; inductor (Lb) current continuous to flow through Cb and secondary inductance supplies the current to the load.
During stage 3, energy stored in $L_b$ is completely transferred to $C_b$ and load continues to get the energy from $L_s$.

4th Stage is begins, when $L_s$ energy is exhausted and $C_o$ is supplies load. Fig.2 shows Working of converter.

![Diagram](image1)

**Fig. 2:** Operating Stages of Integrated PFC Converter.

### 3. Design of fuzzy LPCM controlled integrated converter

The non-linear and imprecise nature of the problem can be effectively solved by using fuzzy logic which gives better performance and reduces the development cost of the end product. The fuzzy LPCM controlled integrated PFC converter is shown in Fig.3.

![Diagram](image2)

**Fig. 3:** Block Diagram of Fuzzy Linear Peak Current Controlled Integrated PFC Converter.

#### 3.1. Identification of inputs and outputs:

The inputs to the fuzzy controller are error ($e$) and change of error ($ce$), i.e., $e = V_o - V_{ref}$ & $ce = e(k) - e(k-1)$, where $V_0$ is the actual output, $V_{ref}$ is the reference output.

#### 3.2. Fuzzifying the inputs and outputs

The inputs are divided triangular shapes of 7 fuzzy sets. Outputs are mapped into fuzzy regions. Fig.4 is membership functions for inputs & outputs.

![Membership Function Plots](image3)

**Fig. 4:** Membership Function Plots.

#### 3.3. Development of the rule base and inference

The rules base table for the present converter is shown in Table 1. The membership functions of 7 variable fuzzy sets, those are negative large (N1), negative medium(N2), negative small(N3), zero(Z), positive large (P1), positive medium(P2), positive small(P3). Triangular shapes are used as a membership function for defuzzification process center of gravity method is used. Rule viewer is shown in Fig.5

<table>
<thead>
<tr>
<th>$e$</th>
<th>$ce$</th>
<th>$e$</th>
<th>$ce$</th>
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<tr>
<td>N1</td>
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</tr>
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<td>N1</td>
<td>N1</td>
<td>P1</td>
</tr>
<tr>
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<td>N1</td>
<td>P1</td>
<td>P3</td>
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<tr>
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<td>P1</td>
<td>Z</td>
<td>F1</td>
</tr>
<tr>
<td>P1</td>
<td>Z</td>
<td>F1</td>
<td>F3</td>
</tr>
</tbody>
</table>

**Table 1:** FLC Rule Base
4. Design example

To meet IEC regulations, considered conduction angle is 1300 to reach highest PF of 0.96 as in ref [4]. Table 2 shows few defined specifications.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Source voltage (V_p)</td>
<td>90-265 V</td>
</tr>
<tr>
<td>Load DC voltage (V_o)</td>
<td>48V</td>
</tr>
<tr>
<td>Power (P_o)</td>
<td>200 W</td>
</tr>
<tr>
<td>Conduction angle (θ)</td>
<td>130°</td>
</tr>
<tr>
<td>Switching frequency (f_s)</td>
<td>100 KHz</td>
</tr>
</tbody>
</table>

5. Results

Fig. 7 shows the implementation of fuzzy peak current controlled integrated PFC converter using MATLAB/Simulink.

Fig. 8 is the AC source voltage & current wave form for 230V (R.M.S) with frequency of 50Hz source current follows the voltage and maintains nearly unity power factor at full load condition. The power factor & source current harmonic percentage are 0.98 and 13%.

Fig. 9 is the load voltage of 48V DC which is the regulated voltage. Fig.10 is the load current of 4.2A DC waveform which is the current taken by the load to meet the 200 W load.

Fig. 11 is the voltage across bus capacitor (Cb) is approximately 140V, which is low as compared to other converters.

Performance of the converter is recorded by varying load from 200W to 100W at 0.25sec depicted in the Fig.12. The observed PF and % THD are 0.97 and 18% respectively.

The results are also recorded by varying the load. It is observed that output voltage is constant despite of change in the load. Therefore output voltage is well regulated. The same fact is depicted in Fig.13 & Fig.14.
6. Conclusion

Design and implementation of fuzzy LPCM controlled buck integrated flyback PFC converter has been presented in this paper. From the simulation results it has been observed that the PF of the converter is 0.98, total harmonic distortion is 13% at full load which is reaching the international standards IEC-61000-3-2 to class-C & D devices and regulated load voltage is 48V has been achieved. Bulk capacitor voltage is 150 V at light load condition which is low as compared to other integrated topologies.

References


