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A NOVEL INTEGRATED BUCK–FLYBACK NONISOLATED PFC CONVERTER WITH HIGH POWER FACTOR

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ABSTRACT: A novel integrated buck-flyback non isolated power factor (PF) correction (PFC) converter is proposed in this paper. This new converter is an inherent integration of a buck converter and a flyback converter, which operates in either flyback mode or buck mode according to whether the input voltage is lower or higher than the output voltage. In this way, the dead zones of ac input current in traditional buck PFC converter are eliminated. Therefore, the proposed integrated buck–flyback non isolated PFC converter can achieve high PF under universal ac input range, and its input current harmonics can easily meet the IEC61000-3-2 Class C limits. The efficiency of the proposed converter is not deteriorated obviously compared to the conventional buck converter. Detailed theoretical analysis and optimal design considerations are presented. A hardware prototype was built up to verify the theoretical analysis of the proposed integrated buck–flyback non isolated PFC converter.

KEYWORDS: **[AC–DC, buck–flyback converter, high efficiency, high power factor (PF).]**

1. INTRODUCTION

As we know, power factor (PF) correction (PFC) technique is well applied to the ac/dc converters because it can provide almost sinusoidal input current. In this way, the ac/dc power converters can meet the IEC61000-3-2 limits. For some special industrial products such as lighting equipment, the PFC converter can also help meet the stricter IEC61000-3-2 Class C limits.

In the past few years, the boost PFC converter was the most popular topology due to its inherent shaping ability of the input current. However, the boost PFC cannot achieve high efficiency at low line because it works with large duty cycle in order to get high voltage conversion gain. Some other topologies such as the SEPIC converter can achieve high PF and reduce the output voltage stress. However, the high voltage stress of switch reduces the efficiency and increases the cost. The buck PFC converter can achieve a relatively high efficiency particularly at low input voltage due to the low average input current and rms current, while the voltage stress of the switch is also low. Therefore, the buck PFC converter has drawn much attention.

Another way to improve the PF of the buck PFC converter is to modify the structure of the conventional buck converter. According to this idea, the integrated quadratic buck–boost–buck converter was proposed. This proposed topology integrates a buck–boost input current shaper with a quadratic buck converter to eliminate the dead zones of the input current and then achieve high PF. However, the complex structure of this topology makes it unsuitable for actual applications. The buck converter can also be integrated with a flyback converter. Two combined buck–flyback converters were introduced in which the dead zones of the input current can be eliminated with the auxiliary flyback converter. However, an additional diode leading to additional losses is inserted in the power loop when these two topologies operate in buck mode.

In this paper, a novel integrated buck–flyback non isolated PFC converter is proposed. The structure of the proposed converter is very simple. It is formed by adding two rectifier diodes, one winding of the inductor, and one switch into the conventional buck PFC converter. The source nodes of the added switch $Q2$ and the buck switch $Q1$ are connected to the ground. Therefore, these two switches can be easily driven without floating drivers. There are two different operation modes in a line period for the proposed converter. The proposed converter operates in flyback mode when the input voltage is lower than the output voltage and operates in buck mode when the input voltage is higher than the output voltage. In this way, there are no dead zones in the input current of the proposed converter. Therefore, it can achieve high PF and pass the IEC61000 Class C limits easily. Moreover, the power loops of the buck mode and flyback mode are separated, and no additional component causing losses is added to the power loops. Obviously, the proposed integrated buck–flyback converter can achieve higher efficiency than the combined buck–flyback converters introduced.

2. RELATED WORKS

L. Huber, E. Brian, T. Irving, and M. M. Jovanovi´c, A systematic analysis of line-current distortions of the discontinuous-conduction-mode and the continuous-conduction-mode boundary boost power factor correction converter due to valley switching (VS) and switching-frequency limitation, where VS is either maintained or lost after the onset of switching-frequency limitation, was provided. Closed-form expressions for the line current are derived. It was shown that if the switching frequency is limited and VS is not maintained, the line current is more distorted with voltage-mode control than with current-mode control. [1].

L. Huber, J. Yungtaek, and M. M. Jovanovi´c,A systematic review of bridgeless power factor correction (PFC) boost rectifiers, also called dual boost PFC rectifiers, was presented by the authors. Performance comparison between the conventional PFC boost rectifier and a representative member of the bridgeless PFC boost rectifier family was performed. Loss analysis and experimental efficiency evaluation for both CCM and DCM/CCM boundary operations were provided.[2]

M. Mahdavi and H. Farzanehfard, A new bridgeless single-ended primary inductance converter power-factor-correction rectifier was introduced. The proposed circuit provides lower conduction losses with reduced components simultaneously. In conventional PFC converters (continuous-conduction-mode boost converter), a voltage loop and a current loop are required for PFC. In the proposed converter, the control circuit was simplified, and no current loop was required while the converter operates in discontinuous conduction mode. [4].

H. Endo, T. Yamashita, and T. Sugiura, A high-power-factor buck converter was proposed by them. The converter was composed of rectifier diodes, a small input capacitor, and a buck converter. It supplies low output voltages and uses low voltage semiconductor devices and ceramic capacitors. Two operation modes exist in the converter: discontinuous and continuous inductor current modes. [6].

X. Li, D. Xu, and X. Zhang, a low cost buck converter was selected as the PFC stage of the electronic ballast metal halide lamp. This paper presented the design of both the main circuit and control loop, analyzed the stability of buck converter, and discussed the function of PFC stage. [8].

3. PROPOSED SYSTEM

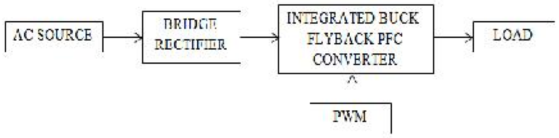


Figure1.Block diagram of proposed system

The proposed system block diagram is shown in the Fig.1. In the proposed system the floating Buck converter is integrated with Flyback converter to form integrated Buck-Flyback converter for PFC.

4. INTEGRATED BUCK–FLYBACK NON ISOLATED PFC CONVERTER OPERATION

The integrated buck–flyback non isolated PFC converter operating in critical conduction mode (CRM) will be analyzed in detail.

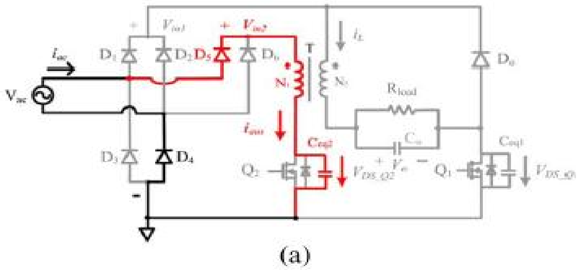
The operation process of the proposed converter in a line period can be divided into 12 operation stages. Shows theequivalent circuits of these operation stages.

1) Positive Half-Cycle of AC Input:When the input voltage Vac is positive and the magnitude of Vac is smaller than V_o, the proposed converter operates in flyback mode. In this mode, switch Q1 keeps off, and switch Q2 keeps switching. There exist three stages when the proposed converter operates in this mode.

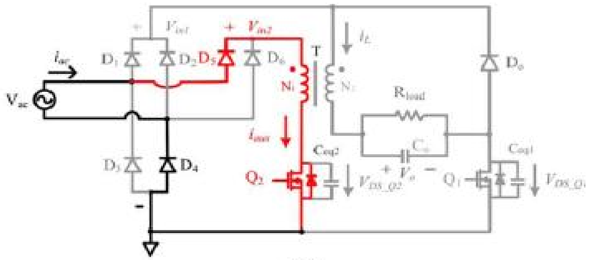
Stage 1) Before this stage, the output diode Do carries the output current, and switch Q2 is off. Once the current flowing through Do falls to zero, Do turns off, and the equivalent capacitor of switch Q2 is resonant with the magnetizing inductor of the transformer T, as shown in Fig below.

Stage 2) When the voltage across the auxiliary winding of the transformer T falls to zero, the output of comparator Uc2 flips from a low voltage level to a high voltage level. After a delay time, switch Q2 is turned on at the valley of VDS_Q2. The primary magnetizing inductor of transformer T is charged by Vac through D5 and D4.

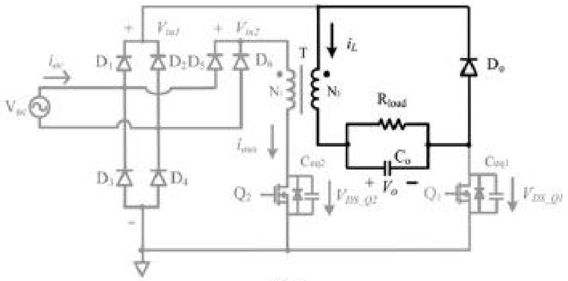
Stage 3) When switch Q2 is off, the secondary magnetizing inductor of transformer T is discharged by Vo through Do on the secondary side of the transformer.



(a)



(b)



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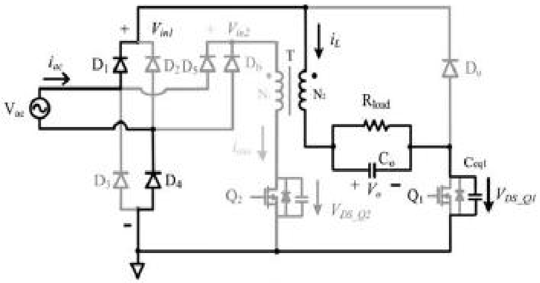
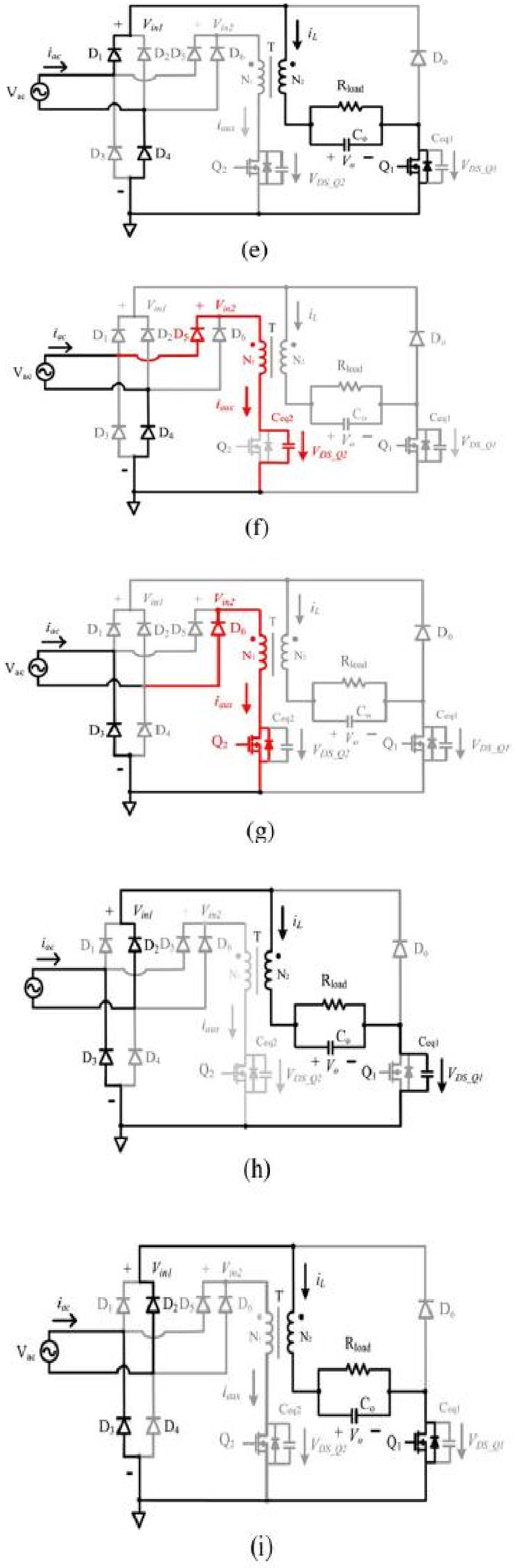


(d)



(e)

(f)

(g)

(h)

(i)

Figure2.Equivalent circuits of the proposed converter

Stage 4) Before this stage, the output diode Do carries the output current, and switch Q1 is off. Once the current flowing through Do falls to zero, Do turns off, and the equivalent capacitor of switch Q2 is resonant with the magnetizing inductor of the transformer.

Stage 5) When the voltage across the auxiliary winding of the transformer falls to zero, the output of comparator Uc2 flips from a low voltage level to a high voltage level. After a delay time, switch Q1 is turned on at the valley of VDS_Q1. The secondary magnetizing inductor of transformer T is charged by Vac− V_0through D1 and D4.

Stage 6) When switch Q1 is off, the secondary magnetizing inductor of transformer T is discharged by Vo through Do.

2) Negative Half-Cycle of AC Input:When the input voltage Vac is negative, the proposed converter also operates in flyback mode and buck mode in different input voltage regions. The operation processes in negative half-cycle of ac input can also be divided into six operation stages, and the equivalent circuits are shown in Fig. The operation processes of the proposed converter in the negative half-cycle of ac input are similar to those of the positive half-cycle.

5. SIMULATION MODULE

5.1 EXISTING SYSTEM

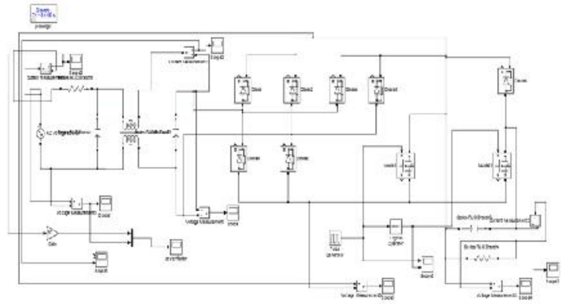


Figure3. Simulation Module of Existing System

The simulation module of the existing system is shown above. The simulation module is designed using MATLAB Simulink. The PF is verified from the input waveform of the system. The waveform is shown below.

6. INPUT VOLTAGE AND CURRENT WAVEFORM

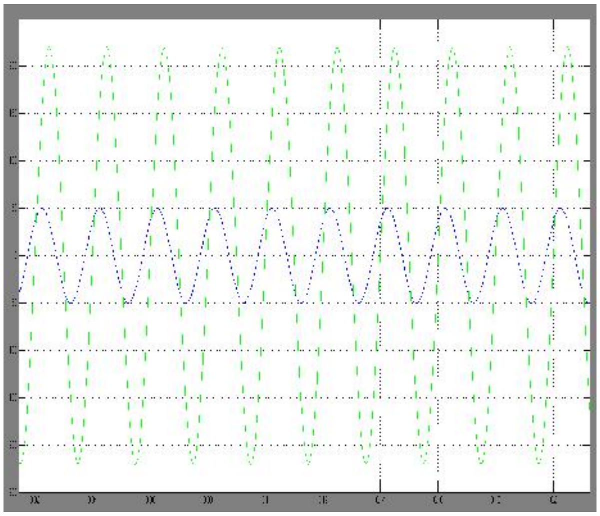


Figure4. Measured Input Current and Voltage of the Existing System

The voltage and current waveforms are not sinking in zero crossing. The Power Factor(PF) of the system is not good.

7. PROPOSED SYSTEM

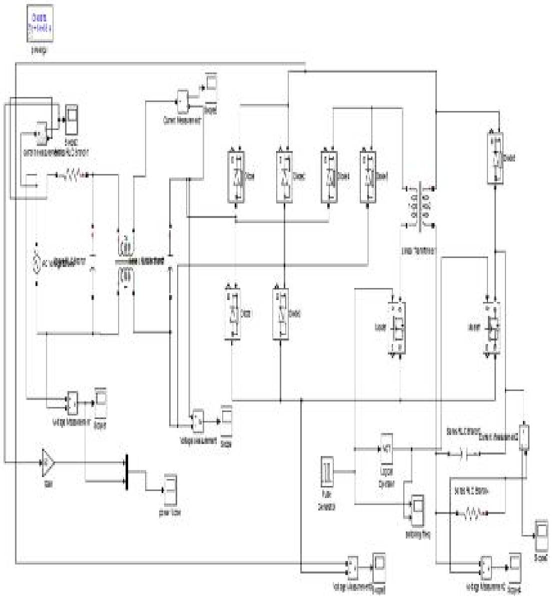


Figure5. Simulation Module of Proposed System

The simulation module of the proposed system is shown above. Here we have integrated the buck converter with flyback system to maintain the PF. The input current and voltage waveform of the system is shown below.

8. INPUT VOLTAGE AND CURRENT WAVEFORM

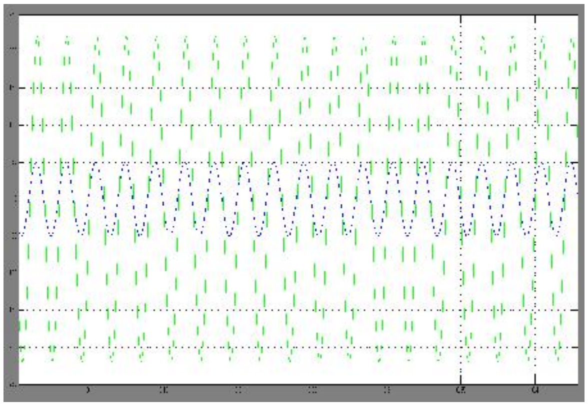


Figure6. Measured Input Current and Voltage of the Proposed System

The input voltage and current waveform are sinks at the time of zero crossing. By comparing the waveform of the proposed system with the conventional system the PF is good in the proposed system.

CONCLUSION

A novel integrated non isolated buck–flyback PFC converter topology has been proposed in this paper. The structure of this topology is simple, and both of the switches are easy to drive. High PF can be achieved for the proposed topology under the universal ac input voltage, and the input current harmonics can meet the IEC61000-3-2 Class C limits. This proposed topology is very suitable for high-power non isolated LED drivers with high PF and high-efficiency requirements. While it is used as the front stage of dc/dc converter, the two floating output ports will cause a severe electromagnetic compatibility (EMC) problem. This issue can be resolved by modifying the buck part in the proposed topology to the classic buck structure with the floating buck switch *Q*1. In this way, only one output port is floating. However, *Q*1 should be driven with a floating driving circuit, and the cost of the modified topology is increased. Beyond that, the merits that existed in the proposed converter have been retained in the modified topology. In addition, the proposed integrated non isolated buck–flyback PFC converter topology can also be extended to isolated topology by replacing the buck part with an isolated buck-type topology such as forward converter.

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