International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 04, April-2015

Control of Bridgeless Flyback Converter

Sumy Thomas
M Tech Scholar
Department of Electrical Engineering
FISAT, Angamaly, Kerala, India

Rakhee R
Assistant Professor
Department of Electrical Engineering
FISAT, Angamaly, Kerala, India

***Abstract*—This paper introduces a new bridgeless flyback rectifier for ac-dc conversion. The rectifier reduces the primary side conduction loss by eliminating the four bridge diodes and efficiency is improved. The circuit does not need any magnetic element and gate driver circuit. Additional elements has minimal effect on circuit simplicity.**

***Index Terms- Bridgless , dual winding , flyback converter, PI controller*.**

I. INTRODUCTION

Flyback converter is one of the most commonly used circuit for SMPS applications. It has topological advantages such as low cost ,simple structure galvanic isolation etc. It is also used as power factor correction (PFC) ac-dc converter. In power factor correction application , there is no in rush current and power factor can be easily achievable by simple control [1].The Flyback circuit is widely used in light emitting diode driver [2]-[4] and micro converters [5]-[7] due to these advantages.

In flyback converter, rectifier diodes cause high conduction loss and it also cause high current stress in semiconductor devices. The efficiency degraded and this limits the flyback topology to low power range of smaller than a hundred watts.

Many methods were introduced to increase the efficiency of the converter. Actively clamping the main switch on the primary side is one of the commonly used method [8]-[11]. The clamp circuit is connected in parallel with the primary of the transformer or the main switch. [12],[13]. It absorbs the stored energy in the leakage inductance and recovers it to Input side. Instead of achieving low voltage stress across the main switch and efficiency it requires additional switch ,its driver circuit and a capacitor.

In conventional LC snubber [16] , the inductor is replaced by an additional winding of transformer is reported in [14] [15].However, the efficiency increase is not remarkable with conventional one, because its performance is sensitive to the leakage inductance.

The soft switching is another method for improving the efficiency by reducing the switching loss of main switch. To minimizing the switching loss in Quasi resonant switching , it maintains minimum drain to source voltage of the main switch at turn-on instant[17]. To find the switching instant during the resonant period ,it requires additional voltage detection circuit. It also requires variable frequency operation which degrades PF.

The bridgeless rectifier concept is one of the most special and effective way to improve the efficiency of ac-dc power conversion. To reduce the conduction loss it eliminates the bridge diodes in the rectifier input side. It maintains the same frequency dynamics with the conventional rectifier. So the conventional control loop can be applied without any change. The bridgeless application applied to boost converter is presented in [18] and in buck converter in [19] .Its application to flyback converter is well presented in [20]-[22].The drawback of bridgeless converter is that it uses two converter ,one for positive line voltage and another for negative line voltage . The circuit simplicity is effected by using more than one magnetic circuit. [23]. The converter presented in [24] has two switches on the primary side and there is no additional transformer. This rectifier is also complicated because the two switches do not share either gate signal or source terminals.

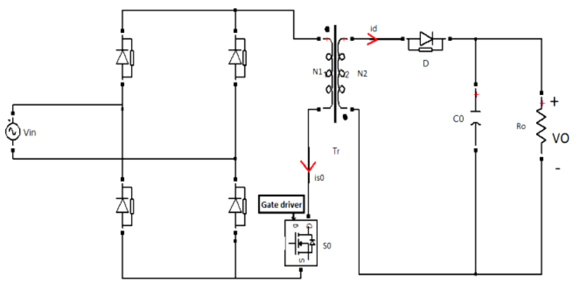
This paper proposes a new bridgeless rectifier with bidirectional switch and dual output winding for improving the efficiency. It reduced the conduction loss by eliminating the four bridge diodes at primary side. The proposed flyback rectifier only introduces a switch, a diode and an additional winding in the transformer. There is no additional magnetic element . The circuit does not require additional gate driver circuit because the additional switch share the same gate signal of main switch. The additional winding on the secondary of transformer is implemented on the same transformer core. There is no need for additional magnetic core.

This paper shows the operational analysis and simulation results of the proposed flyback rectifier .The controlled operation is also presented in this paper. In section II the structure and the principle of operations are explained. In section III the transformer design was explained. In section IV the simulation results of both open loop and closed loop circuit are presented and the conclusion is presented in section V.

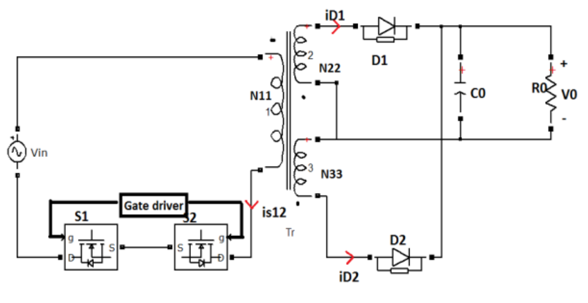
II. PROPOSED BRIDGELESS FLYBACK RECTIFIER

A. *circuit structure and principle of operation*

The fig 1 shows the conventional flyback rectifier with bridge diodes and proposed rectifier without diodes. The proposed rectifier in fig 1(b) eliminates the four bridge diodes of conventional flyback rectifier as shown in fig 1(a). By eliminating the bridge diodes in the input side, it reduces the primary side conduction loss.



(a)



(b)

Fig 1: conventional (a) and proposed bridgeless rectifier circuit configuration (b).

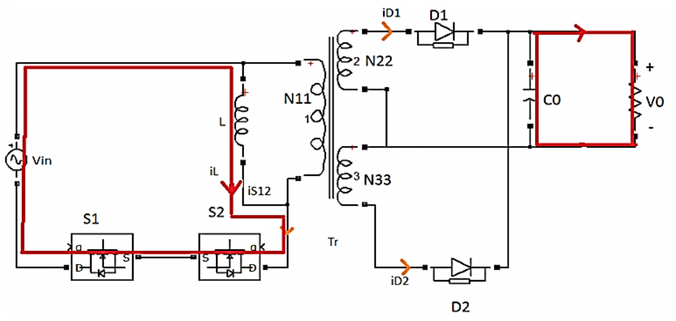
In proposed bridgeless flyback rectifier , few more components are added to circuit to compensate the elimination of diodes. The additional elements does effect the circuit complexity . The additional components on the proposed rectifier fig (b) are switch S1 on the primary side, a diode D2 on the secondary winding and additional winding N33 on the secondary .The additional components maintains the circuit simplicity to preserve the inherent advantage of flyback converter.

The additional switch S1 shares the same gate signal and source terminal with main switch S2. So the additional gate driver circuit is eliminated. The stress on both D1 and D2 is reduced by the addition of diode D2 to the secondary of transformer . The diode current iD0 in the conventional circuit fig(a) is divided into iD1 and iD2 in the proposed circuit fig(b). The two diode current makes the heat management of *D*1 and *D*2 easier than that of *D*0 . The additional secondary winding turns N33 is made equal to N22. The additional winding occupies negligible area in the printed circuit board because it is physically inside the transformer. Generally in flyback converter less winding on secondary.so the addition of N33 has no effect on transformer core. Thus in other words it can say that , it is easier to add another winding in secondary than on primary [24].

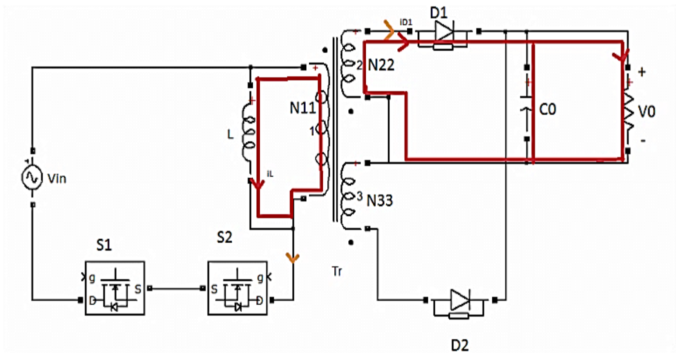
The proposed rectifier operates in constant-duty fixed frequency DCM of operation. It controlled by a simple low-bandwidth voltage loop. The operation acquires high PF and low current distortion without any current control. This is because the average switch current iS12 per switching period is naturally proportional to the instantaneous line voltage Vin.

The proposed rectifier has four equivalent topological states in the steady-state operation according to the line voltage polarity and switching state as shown in Fig. 2. Assumption is that the transformer has zero leakage inductance and the semiconductor devices have negligible on-state resistance and forward voltage drop. The four states are similar to the conventional flyback converter. L and iL are the transformer magnetizing inductance and current respectively. Figs. 3(a) to 3(b) represents state 1 to 2 which shows the circuit operation when input voltage is positive, i.e., vin > 0. In these states , *N*33 and *D*2 do not participate in the rectifier operation and conduct no current.

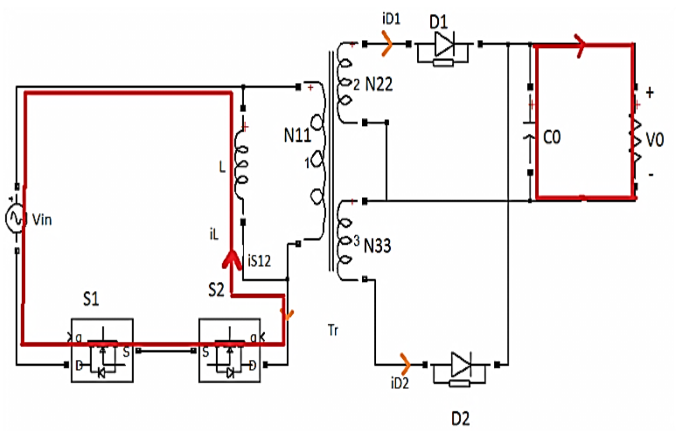
State 1 begins when *S*1 and *S*2 turn ON and the positive *V*in stores energy in L as in Fig. 2(a).The *i*L and *i*S12 increase linearly and the output capacitor *CO* supplies power to the load. The transformer design criterion such as (1) should be met to avoid the unexpected turn-on of diode *D*2 , which will be explained in Section III When switch S1 and S2 turns off in state 2 as in Fig. 2(b), magnetic flux in *L* discharges through N22 and D1 to load. The winding N33 and output diode D2 does not participate in the operation. When vin turns negative, vin < 0, states from 3 to 4 occurs as from Figs. 3(c) to 3(d) and N33 and D2 operates. In state 3, when S1 and S2 is on as in Fig. 3(c), Negative vin charges L with the opposite direction. When S1 and S2 turn off in state 4 as shown in Fig. 2(d) the flux in L discharges through N33 and D2 . In this state D1 is reverse-biased and N2 2 does not carry any current.



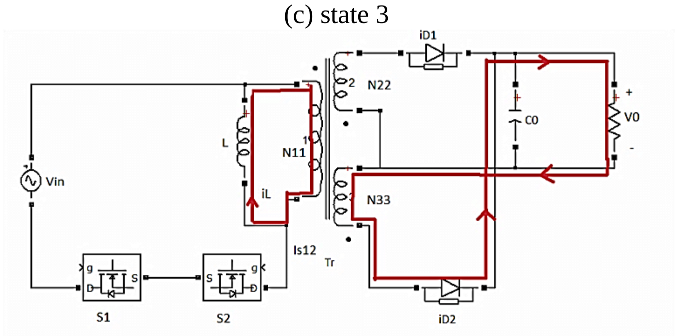
(a) state 1



(b) state 2



(c) state 3



(d) state 4

Fig. 2. four operational states of the proposed flyback rectifier:

III. DESIGN OF THE RECTIFIER

A. *Transformer Design*

The transformer T design for the bridgeless flyback rectifier should include two design parameters , the magnetizing inductance L and the turn ratio of the windings, N11:N22:N33. The winding turn ratio should be properly selected to guarantee the stable operation of the rectifier. The turn ratio of *N22* to *N33* is designed to be same to meet the voltage gain whether the polarity of *vin* is positive or negative. The turns ratio should be designed to satisfy (1)

$$\frac{N22}{N11} = \frac{N33}{N11} \frac{V0}{Vin{-}pk} \qquad (1)$$

Where V_O is output voltage and vin_pk is maximum instantaneous input voltage . If the design criterion in (1) is not met, one of the output diode will be short-circuited and the operation of the rectifier will be unstable. For example, in Fig. 2(a), *D2* may turn on unexpectedly because the voltage across *D2* is not sufficient to reverse-bias it. similarly *D1* may turn ON in state 5 unexpectedly in fig 2(d) if (1) is not satisfied. The design condition for *L* is to make it smaller than a certain value not to operate the rectifier in unexpected CCM [25].

IV. SIMULATION RESULTS

The bridgeless flyback converter of 70 W is simulated . The input to the converter is 140 V ac and the output obtained is 48V dc. The gating signal is obtained using PWM block and it is given to the gate of switch.

The simulation diagram for control of flyback converter has been given below. In order to maintain voltage constant for particular application and to reduce the steady state error , a PI controller is used. The output of the controller is then given to PWM block which compares it with triangular wave and generate gate signal for the switches in the flyback converter. The output voltage is maintained at 48 V.

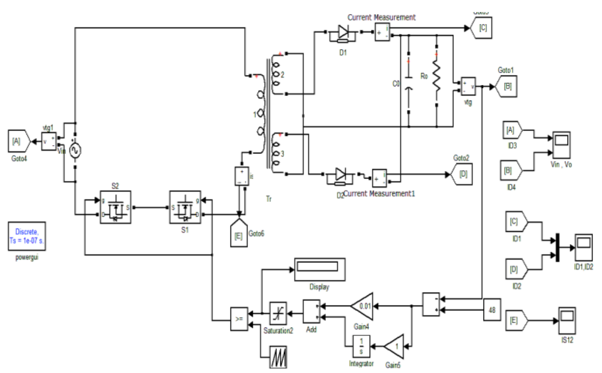


Fig. 4 Closed loop simulation model for control of LED system using interleaved flyback converter.

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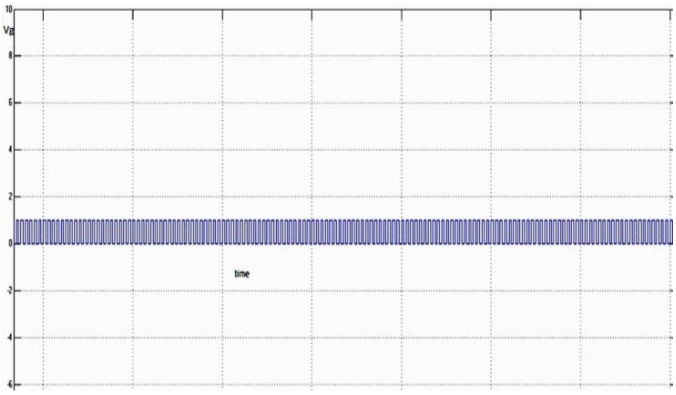
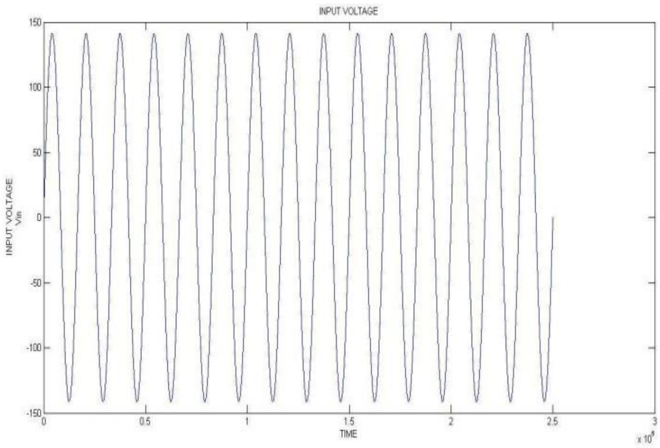
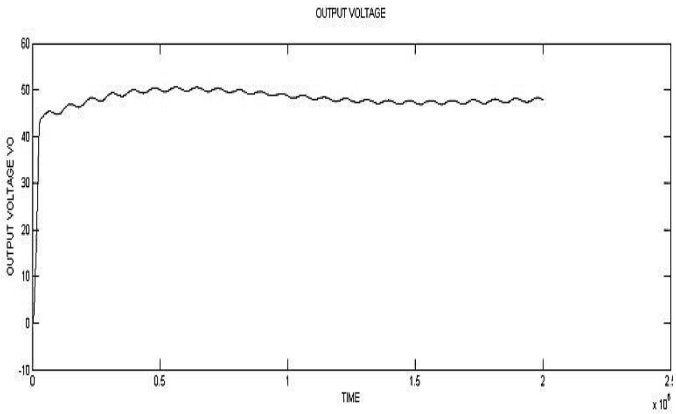
A. RESULTS



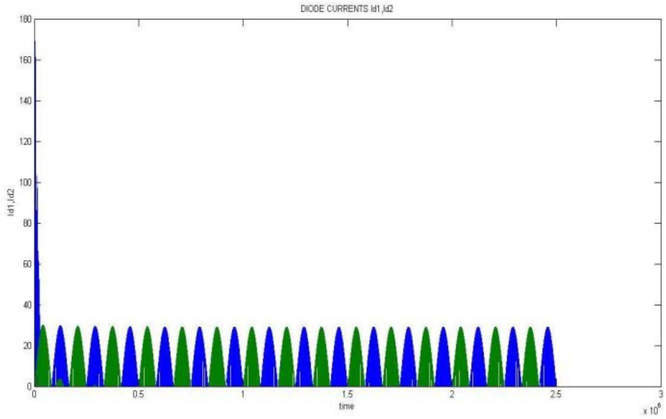
(a). Gate pulse for S1 and S2



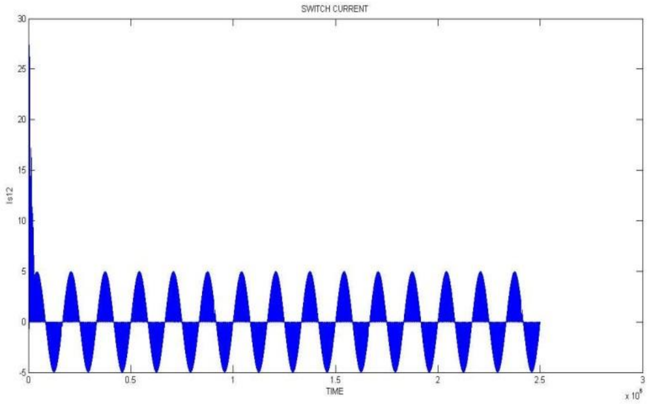
(b). Input Voltage



(c). Output Voltage



(d). Diode currents



(e). Switching current

Fig 5: simulation results

The gate pulses ,input voltage , output voltage ,diode currents and switching current for the closed loop simulation model of the controlled flyback converter is shown in fig 5. When the input voltage of 140 V is given ,the output voltage of 48V is obtained. The steady state error is minimized and efficiency is increased.

V. CONCLUSION

A controlled bridgeless flyback rectifier for ac–dc conversion has been proposed in this paper. The rectifier is derived from the conventional flyback converter. it eliminates the four bridge diode at the primary side and adding a switch on input side and a diode-winding pair at the secondary of transformer. The additional elements maintains the circuit simplicity. The additional switch and winding does not any additional gate driver circuit and magnetic core. The circuit improves the efficiency by reducing the conduction loss due to four bridge diodes. The output can be maintain constant and steady state error can be decreased by using PI controller. Thus efficiency can be further increased.

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