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High Power Factor LED Driver using PWM Rectifiers

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Abstract: An improved topology is proposed here with forward flyback converter having PWM rectifiers at the input side in order to achieve unity power factor . Buck converter is inserted between the forward sub converter and load. Here "One and a half stage" converter scheme is proposed where most of the power reaches the load through flyback sub converter and a small portion through forward sub converter and buck converter. Electrolytic capacitor can be eliminated, thus the lifetime of driver can be improved. Bus voltage between forward sub converter and cascaded buck converter is auto regulated for achieving power balance. The proposed driver has higher efficiency than conventional AC-DC led drivers. Ripple compensation control is done in the proposed scheme. Hysterisis control is used for switching PWM rectifiers in order to improve the power factor and hence THD is reduced. Proposed topology is very suitable for industrial application such as low power AC-DC led drivers.

Keywords: PWM Rectifiers, Forward - Flyback Converter, Power Factor Correction, Ripple Compensation, Hysteresis Control, THD (Total Harmonic Distortion)

I. INTRODUCTION

The Light Emitting Diode (LED), with its major characteristics of high brightness, long lifetime and high efficiency, had gradually replaced the traditional lighting equipments in our daily life. However, the general operating life of conventional AC-DC LED drivers is much lesser than the estimated lifetime of LEDs (50,000h)[1]. The main reason for this problem is the short lifetime of the electrolytic capacitor used in the equipments .so it is the capacitors which is limiting the lifespan of LED drivers.

The Power Factor (PF) and Total Harmonic Distortion (THD) of input current are also important problems affecting the performance of AC-DC LED drivers. In order to achieve high PF and low THD, the input current has to follow the shape of input voltage waveform during a line cycle or simply saying, the waveforms of input current and input voltage should be in phase. The LED's brightness is determined by input dc current, so a good LED driver should guarantee the constant output power Po.

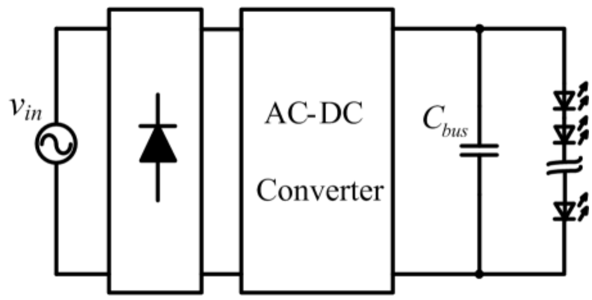

Fig1: Single stage topology

The single-stage AC-DC led driver topology is well used for low-cost design . The single-stage circuit can achieve high efficiency, but there will be always an existence of large output ripple current. Large capacitance of E-cap(Electrolytic capacitors) paralleled with the LED load can help to reduce the output ripple current. The same may also be obtained with film or ceramic capacitors which have much longer lifetime, but which increases the cost of converter greatly. Therefore, it is not feasible to eliminate E-cap from the single-stage AC-DC LED driver.

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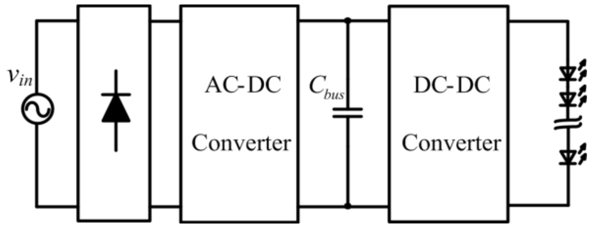

Fig2:Two – stage topology

The two-stage AC-DC LED drivers [2]shown in Fig.2 can achieve high PF and low output ripple current due to the high band-width of the second stage converter. But the power is processed twice. The electrolytic capacitor Cbus paralleled between the two stages in order to balance the variation of instantaneous power between the two converter stages is much smaller than that in the case of single-stage AC-DC driver. Hence from the above knowledge, here introducing a one and a half stage AC-DC LED driver in the proposed system.

II. SYSTEM DESCRIPTION

1. PWM RECTIFIERS

The single-phase PWM rectifier is now becoming more popular due to its low distortion input current, unity power factor operation and bi-directional power flow ability. In general, the selection of an appropriate controller of a PWM rectifier requires good knowledge about the characteristics of the system to be controlled[3]. For the positive half cycle the switches S2, S3 and body diodes D1 ,D4 will get forward biased. Turn on the switch S2.The conduction path for this operation is VS-L-S2-D4. Source is connected to inductor and hence current through inductor(source current) will rise. Turn off the switch S2. Now conduction path will be Vs-L-D1-Load-D4.

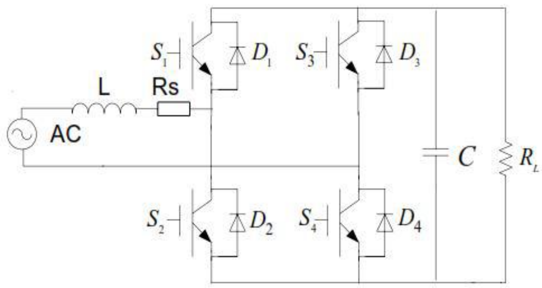

Fig3: PWM rectifier using four IGBTs

For Negative half cycle the switches S1,S4 and body diodes D2,D3 will get forward biased. Now the current control is carried out by switch S1. By turning ON and OFF of this switch S1 current can rise and fall respectively. Hence for positive half cycle turn ON and OFF of switch S2 controls the source current and for negative half cycle turn ON and OFF of switch S1 controls the source current. It can be concluded that for rectification operation S1 and S2 IGBTs are enough and S3,S4 are not used. Thus we introduce the PWM rectifier with two switches instead of diode bridge rectifiers and filter at the input of the proposed structure

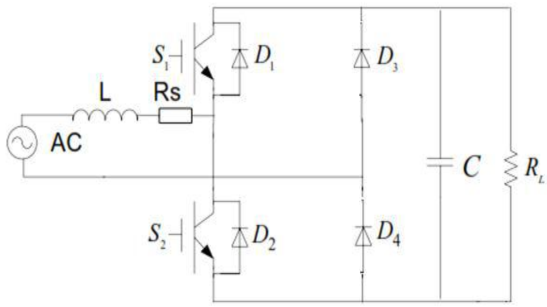

Fig3: PWM rectifier using two IGBTs

The rectification is done through the diodes and it is controlled by the switches S1 and S2.

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2. FORWARD FLYBACK CONVERTER

Forward converter and flyback converter are the two popular switched mode power supply (SMPS) that is used for producing isolated and controlled dc voltage from the unregulated dc input supply. Here, in the proposed system, by combining both the converters to act as a single three winding transformer named forward flyback converter [4]. Flyback converter is derived from the buckboost converters. So, the voltage transfer ratio depends on the duty ratio (D) as in the case of buckboost converters.

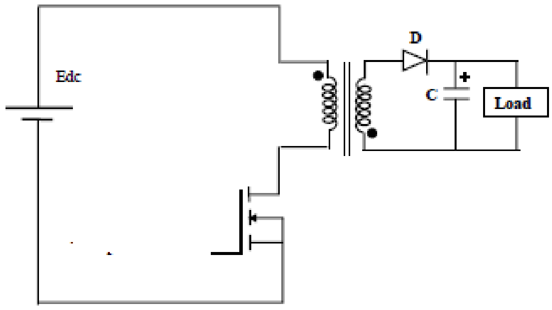

Fig5(a): Flyback transformer structure

$$V_0/Edc = (N2/N1)\ (D/(1-D)) \qquad (1)$$

Forward converter is derived from step down converters or buck converters. So, voltage transfer ratio is proportional to the duty ratio (D) similar to that of buck converters.

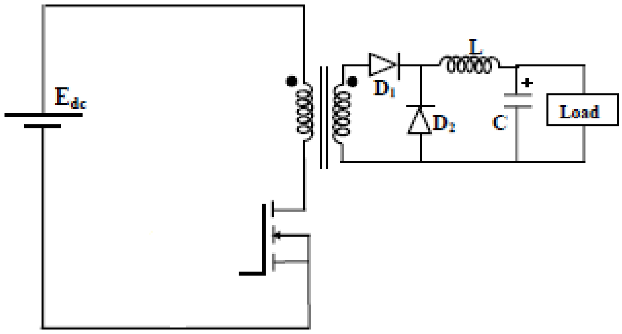

Fig5(b): Forward converter structure

$$V_0/Edc = (N3/N1)D \qquad (2)$$

Where V_0 is the voltage across the load

From the above equations, the duty ratio for forward-flyback converter can be obtained. Buck converter is used as DC-DC converter at the output stage in the proposed structure.

III. CONTROL SCHEME

In the proposed driver, two converter switches are performing the voltage ripple compensation control scheme. Thus the proposed system has two stage ripple compensation .Hence output ripple content can be reduced in the proposed AC-DC led driver. Thus by reducing the voltage ripple, current ripple can also be reduced. In the voltage ripple compensation scheme, output voltage is compared with the reference voltage and the error voltage is used for producing the gate signal to trigger the converter switches. In PWM rectifiers, as we have already discussed there is a two switch configuration. The control scheme used here is the hysteresis control. Output of PI controller decides the magnitude of current to be drawn from the source which depends on the required reference voltage. From the source voltage, unit sine template is obtained and the reference current is obtained by multiplying the required magnitude of current and unit sine template. Hence the reference source current is obtained. The actual current through the inductor(actual source current) is controlled using hysteresis current control method [5], source current can be controlled to be sinusoidal and in phase with the source voltage. Thus input power factor can be controlled.

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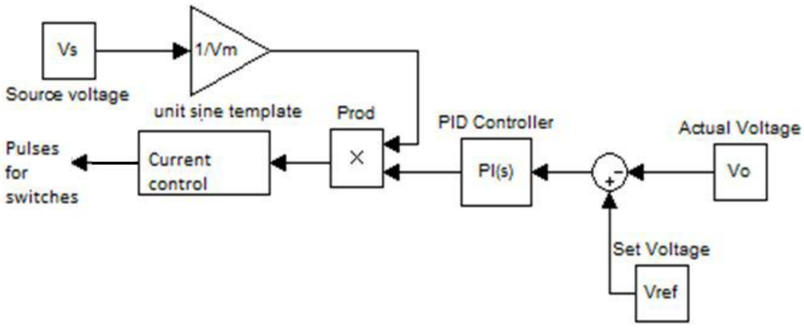

Fig6:hysteresis control scheme

IV. PROPOSED SYSTEM

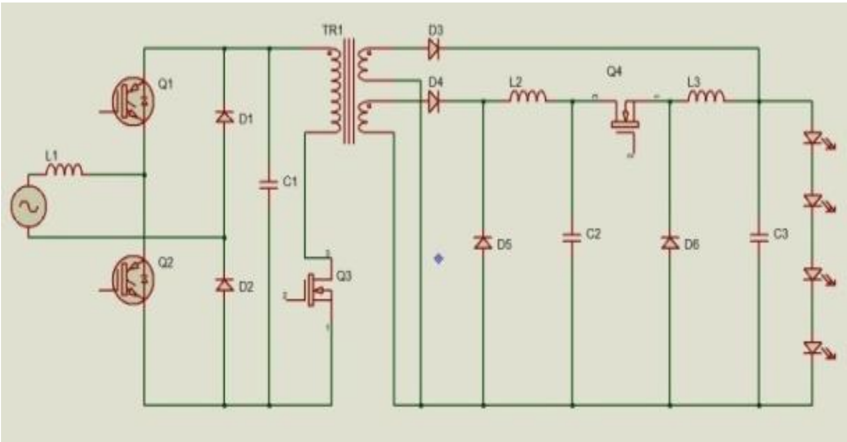

Fig7: Proposed AC-DC led driver

The proposed led driver with PWM rectifiers at the input of forward-flyback converter is described and implemented. Hence the input power factor is improved. Total harmonic distortion is now reduced. Hysterisis control is use for achieving unity power factor in PWM rectifiers .Hence by using PWM rectifiers with two switches, thus switching loss can be reduced and thus efficiency can be increased.

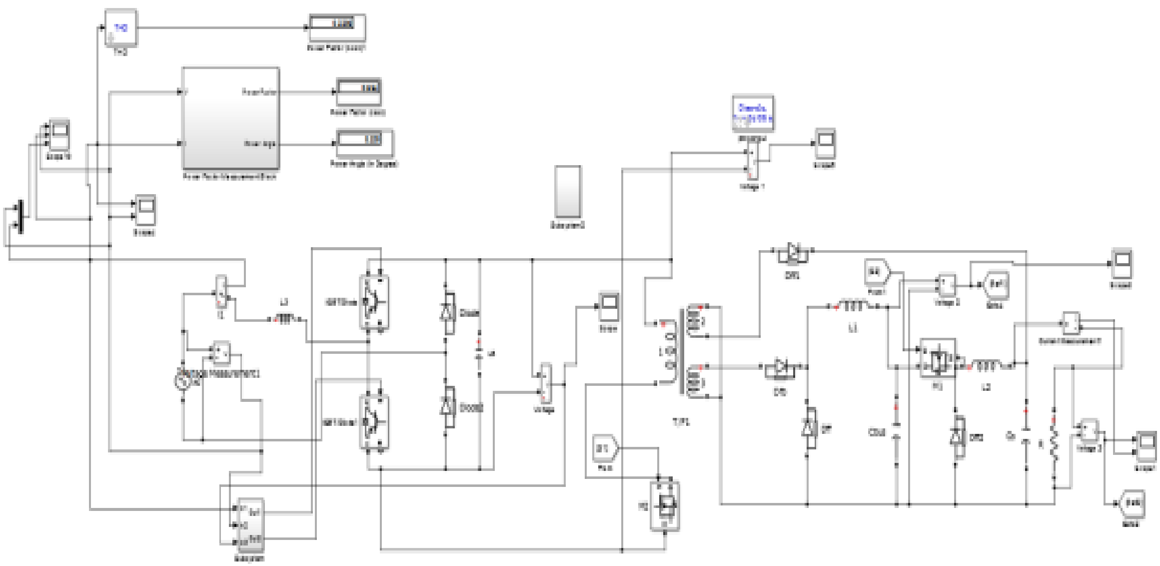

Fig8: Simulation diagram of proposed system in MATLAB/Simulink

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By voltage ripple compensation scheme, the proposed driver can obtain a controlled and constant dc output voltage and dc output current with reduced ripple. Hence performance of led driver is improved

V. SIMULATION RESULTS

Fig 8 shows the simulation diagram of the proposed led driver using MATLAB/Simulink. Simulation results obtained is also shown.A20W prototype is simulated here. Fig 9 shows the dc output voltage and dc output current. Fig 10 shows the input voltage, input current and the waveform showing the phase delay between two waveforms. From the Fig 10, it is clear that the input current is following the shape of input voltage .Hence the power factor obtained is 0.998. Power factor and THD are related by the equation,

Power factor,

Pf=displacement factor*distortion factor (3)

Distortion factor=1/√(1+(THD)^2) (4)

From the above equation value of THD also affect power factor .Here the value of THD obtained is 3.24%.

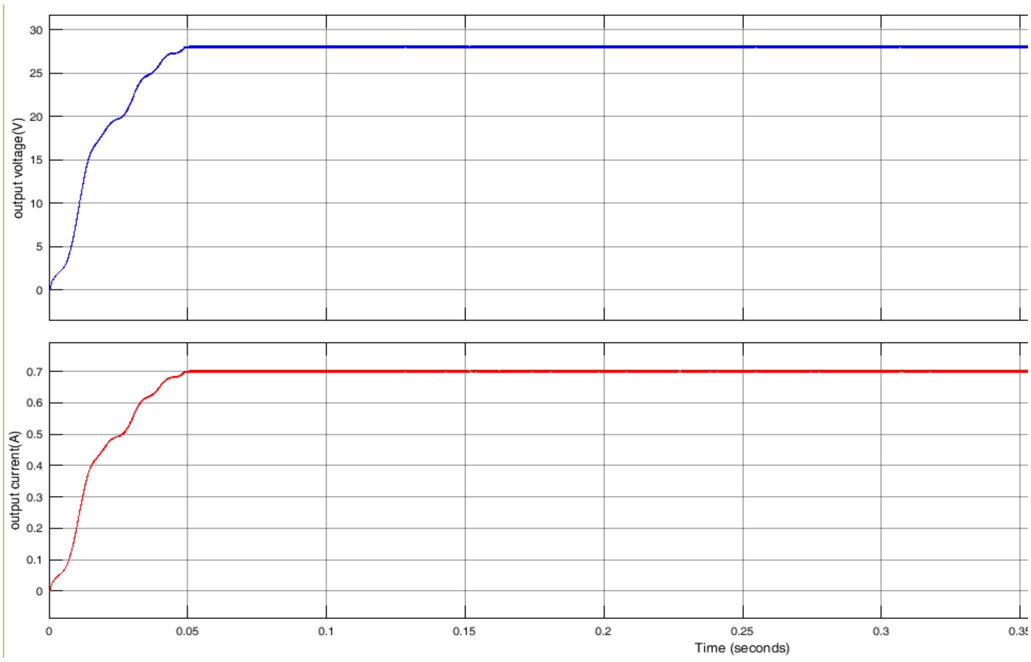

Fig9: Output voltage and output current

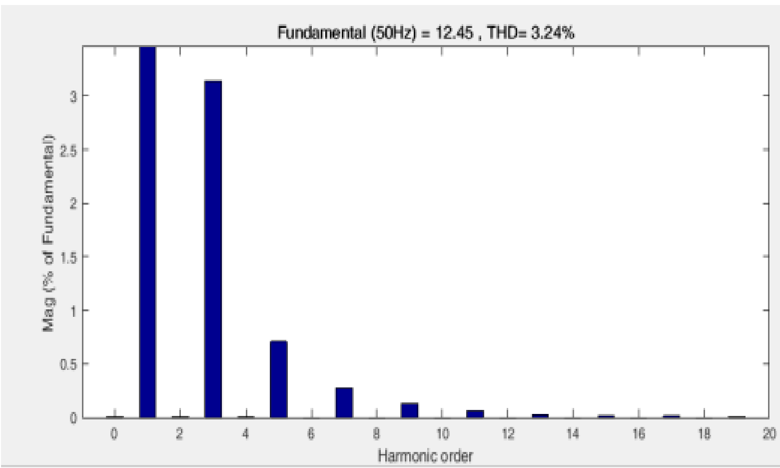

Fig10: THD value of the proposed system

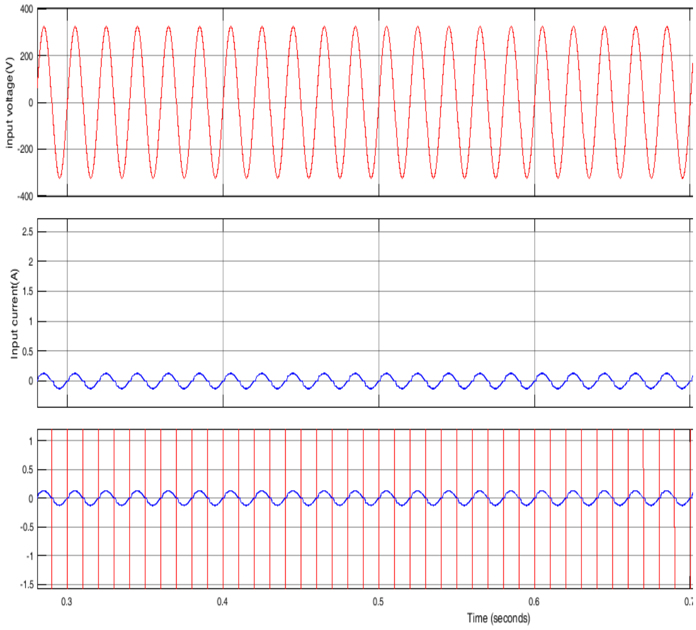

Fig11: Simulation results showing the in phase waveform of input voltage and input current

VI. CONCLUSION

An improved forward-flyback topology for 28V/700 mA prototype of AC-DC LED driver with universal input has been proposed and studied in this paper. A buck converter is inserted between the forward sub converter and the output load. Ripple compensation is done using two stage control scheme. Current ripple is reduced to 5 mA which is below 1% of output current and voltage ripple is reduced to 0.15V which is below 1% of output voltage. The efficiency of proposed topology is 86%, which is much higher than the two-stage E-cap-less PFC converter The proposed converter can achieve high power factor, high efficiency and low output ripple without electrolytic capacitors. In conclusion, the proposed topology is very suitable for industrial applications such as low power AC-DCLED drivers.

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