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Hydro carbon emission reduction by using an efficient Two stage LED Street Lighting System with fly-back and sepic converter

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ABSTRACT

Hydro carbon emission from conventional energy sources like thermal stations can be indirectly reduced by decreasing the power loss of the electrical load. An efficient two-stage street lighting system is proposed that consumes less power. The first stage is an interleaved AC/DC converter based on fly-back converter and sepic circuits and the second stage consists of constant current circuit based on boost converter. The proposed interleaved method uses reduced switches with increased efficiency. It was found that the proposed technique reduces the total harmonics distortion (THD).A 100W prototype is developed which satisfies the functionalities of the proposed LED circuits.

Keywords: -LED, Street Lighting Systems, Interleaved Converter

INTRODUCTION

LEDs replaces CFL in this new era. The LED's are highly preferred because; it has the features of smaller size, larger lifetime and low maintenance costs (ManuelArias, 2012). LED's are used in applications like displays, street lighting, decorative lighting, automotive lighting and motor cycle lighting (Yijie Wang, 2013). Since the current flowing through the LED is unidirectional, it produces a direct emission of light. Nowadays, high-brightness light emitting diodes are used for lighting application because of their outstanding advantages such as high luminous efficiency and lifetime of around 50,000 hours, which depends on the operating temperature. This is used in intelligent lighting because of easy turn on and turns off and it resists vibrations and shock (H.-B. Ma1, 2013). Since mercury, filament or gas is not used in the production of LED's, it is environmental friendly. The LED driver needs the voltage between 140 to 12V and current between 350mA to 5A. The LED driver has three parts such as power factor correction (PFC) circuit, DC-DC voltage regulated circuit and constant current circuit. The PFC circuit is achieved when the boost converter is made to operate in discontinuous conduction mode. The voltage regulated circuit is produced with the help of fly-back converter. The constant current circuit is obtained by PWM dimming control method and it can also be used for power saving (Yijie Wang, 2013). In lighting application when the input power increases above 25W, the IEC-61000-3-2-class c standard is used to check the THD of the system (R.Sreemallika, 2014). The first stage AC/DC converter based on buck circuit and fly-back converter is used to drive the LEDs, but the dead zone in power circuit produces very low power factor. When the boost circuit and the fly-back converter are integrated to drive the LEDs it increases the voltage stress. The buck-boost circuit and also the fly-back converter is used to operate the circuit in DCM mode and is used to increase the regulation of the output voltage. So, the buck-boost converter is the better choice to improve the output voltage (Yijie Wang, 2013).

The fly-back converter is used for low power application where, the isolation is mandatory (Chun-An Cheng, 2013). This buck-boost circuit with fly-back converter can provide high power factor, high conversion efficiency and lower THD. The buck-boost circuit has the function of shaping the power factor and also is used to convert time varying rectified line voltage to stable DC-link voltage. In fly-back converter, a large output capacitor is used to satisfy the holdup time and to reduce the output voltage ripple at twice the line frequency (VivekNaithani, 2012). The diode is connected between the switch and the transformer primary side. The converter cannot work in ZVS state because; the switch cannot work in quasi-resonant state. The single ended primary inductive converter (SEPIC) is a DC/DC converter which is used for LED lighting system. It provides regulated output voltage from input voltage. This sepic converter is also used as a current shaper for LED driver. The filter inductor value is reduced by having two inductors, one on the input and the other on the output side so that the power supply is made large. Instead of using step up and step down transformer to make the output voltage as DC bus voltage the sepic converter is used. Interleaved converter has fast transient response; two output stages are 180 degree out of phase. By dividing the current into two power paths, conduction losses can be reduced and the efficiency is increased. To drive the LED driver with a constant current control and better luminous efficiency the boost circuit is made use of its simplicity and its suitability for LED string applications. A two stage LED street lighting system with interleaved concept is proposed in this paper. The first stage is an AC/DC converter based on sepic and fly-back circuit. The sepic circuit is used for PFC function when it is operated in DCM mode. The fly-back circuit is used to increase the efficiency and decrease the switching loss when it is working in quasi-resonant state. The second stage is a constant current circuit which is achieved when the boost circuit is operated in peak current control mode. Here, the constant current control is realized by LT3756, LINEAR Company. The description of proposed LED driver is presented with fly back converter and sepic circuits.

Proposed LED Driver: The proposed driver reduces the switching loss, THD and increases the efficiency. To operate the converter in high voltage input state and continuous input current, the interleaved AC/DC converter is proposed. The cost of the system is reduced and the reliability and efficiency of the system is improved because the circuit works in quasi-resonant state which makes the switch operate in ZVS condition. As Shown in figure 1, the first stage of the sepic converter has L1, C1, L2, D6, C3 and Q, whereas the fly-back circuit has Q,transformer,D7,C4 and load. The two circuits are integrated in such a way that the switch Q is shared by the two circuits and both these circuits are working in DCM state. The fly-back circuit produces constant DC bus voltage and sepic circuit is for PFC function.

Modes of Operation: The converter has four working modes.

Mode 1 (t0-t1): The mode begins at t0. The driver signal turns on switch Q and the current through L1 increases linearly. C1&C6 discharges to L2&L4 through D5 and Q. C3&C7 discharges to transformer primary side through Q. The magnetizing current increases linearly and the mode ends at t1. At this moment, the turn-off signal arrives and Q is turned off.

Mode 2 (t1-t2): Q is turned off at t1. L1 freewheels through C1, D6. Charges to C3 andL3 freewheels through C6, D9; L2 current discharges to C3 through D6 and L4 discharges to C7 through D9. The secondary side of the transformer provides energy to the load through D7. Here, the moment at which the current of D6 decreases from the peak to zero is represented as t21 and the off moment of equals to the current of L2, this mode ends.

Mode 3-1 (t2-t3): At t22>t21, the mode begins at t2 and the current of D6, D9 is 0. The secondary side of the fly back circuit still continues to provide energy to the load, and the mode ends at t3 when the current in the secondary side is 0. Mode 4-1 (t2-t3): As shown in fig.2d, t21>t22, The current in the secondary side of the fly back circuit is 0; the primary side inductance resonates with the primary side equivalent capacitance C2 and the voltage across Q reduces gradually. At this time, L1 is freewheeling; L2 is clamped by the output voltage; so the current of L2 decreases to 0 and then increases reversely. When the current of L1 equals to the current of L2, this mode ends.

Mode 4-1 (t2-t3): At t21>t22, The current in the secondary side of the fly back circuit is 0; the primary side inductance resonates with the primary side equivalent capacitance C2 and the voltage across Q reduces gradually. At this time, L1 is freewheeling; L2 is clamped by the output voltage; so the current of L2 decreases to 0 and then increases reversely. When the current of L1 equals to the current of L2, this mode ends.

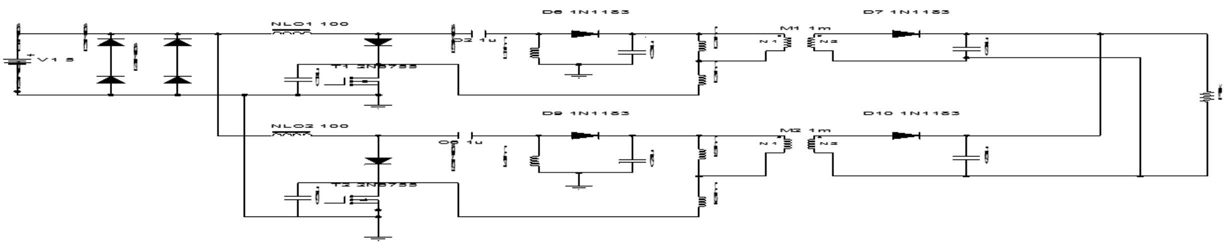

Figure.1.Proposed interleaved AC/DC converter based on sepic and fly back circuit

CALCULATION

The constant current control is used here to drive the LED's. The control chip LT3756 is provided by LINEAR Company. It is a DC/DC controller designed to operate as a constant current source for driving high current LED's. They drive the switch at 7.15V. It gives stable operation over a wide range of supply and high side current sensing is the most flexible scheme for LED's. The 100W prototype is proposed for 350mA/3.3V LED's by considering both the applications and the costs.

Here, the input voltage is 230VAC,Vd=0.0023V,Io=206A and the duty cycle is D=0.5 then the conduction loss of the proposed system will be

Pcond = 0.0023*2.6*0.5

= 0.00299

The switching loss calculation is done with the help of equation 2.

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$$P_s = \tfrac{1}{2} V_d I_o f_s \left[t_{c(on)} + t_{c(off)} \right] \quad (2)$$

Where

Ps-switching loss in watts, Vd-input voltage, Io-input current

Fs-switching frequency, Tc(on)-turn on delay time, Tc(off)-turn off delay time. Here, the input voltage is 220VAC, Vd=400V,Io=20A switching frequency Fs=20Khz,and the turn on & turn off time of the switch is 16microseconds & 49microseconds respectively. Then the conduction loss of the proposed system will be Ps=0.676watts Ps=400*2.6*20000*[16usec+49usec].

Simulation results: In this paper, 100W rated output power prototype has been successfully built in order to power the street lighting system with the LED string. Table I shows the parameter of AC/DC converter of the proposed LED driver. To simulate the constant current LT3756 is used here. Fig.3. shows the output of voltage and output current of the proposed system with the resistive load of 100ohms and Fig2 shows the total harmonics of the proposed system. The output voltage of the sepic converter is in the range of 460V and the output voltage of the proposed system is 21.5V.The power factor is as high as 0.992, the THD is as low as 6.9% and the efficiency of the system is 84%. When the output power ranges from 30 to 75W, THD of the system is within the range of 10% and the efficiency is about 0.99.

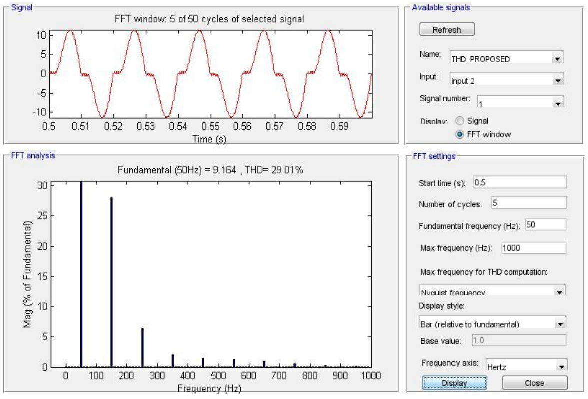

Figure.2.THD of the proposed system

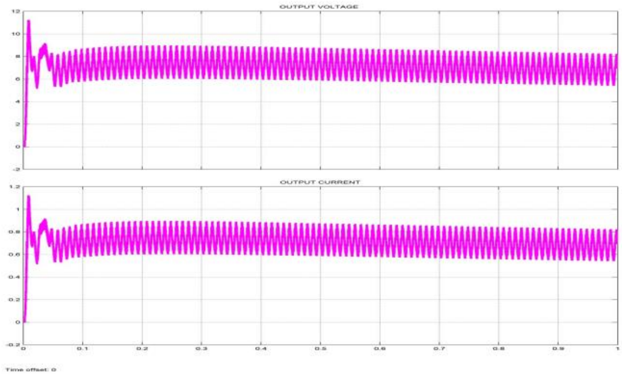

Figure.3.Output voltage and current of the proposed hardware circuit

CONCLUSION

Pollution can be decreased by reducing the emission of carbon from a thermal station which requires the electrical loads connected to the grid to be operated efficiently with less electric power loss. An efficient two stage interleaved street lighting system is proposed in this paper. The first stage constitutes the interleaved sepic circuits & AC/DC converter based fly back converter. Since, a single switch is shared and works in the quasi resonant state, the conduction loss and also the switching loss of the system decreases and the efficiency is improved. The second stage is a constant current control mode and it is achieved by working a boost circuit in peak current control mode, adopting LT3756 as the control chip. In this system IEC 61000-3-2 standard is met for power factor & the total harmonic factor. The overall efficiency is 84% in the full load condition. Considering the low cost and high reliability the proposed system is suitable for LED lighting applications.

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