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Electronic Ballast for High Intensity Discharge Lamp Based On AC-AC Sepic Converter

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Abstract— This project work proposes SEPIC converter topology for developing electronic ballasts, supplying high-intensity discharge lamps fed by a pulse width-modulation ac–ac converter, implemented with bidirectional switches. The lamp operates directly from the ac mains; thus, the drawbacks of the low frequency square waveform operation get eliminated. The features of the proposed solution are high efficiency, high power factor, low cost, and the absence of electrolytic capacitors. This paper includes the design of passive elements.

Keywords: AC–AC conversion, acoustic resonance (AR) phenomenon, ballasts, current control, high-intensity discharge (HID), ignition, lamps.

I. INTRODUCTION

High intensity discharge lamp lighting systems are widely used in high-intensity light level for the application of vehicle headlight, industrial and street lighting. These lamps have average life spans are more than 26 000 h long, and they produce light with efficiency higher than 90 lm/W. Previously, magnetic ballasts were using for HID lighting systems, but they introduce bulky inductors to limit the lamp current and to provide ignition .Next proposes Electro Magnetic Ballast .Advantages of Electromagnetic ballasts was low cost simplicity and reliability .But again there comes the drawback of large size and weight and they possesses poor power regulation and sensitivity to line voltage sags . Nowadays, high-efficiency electronic high intensity discharge lamp electronic ballasts are also available and can provide an increased lighting quality. The cost of the electromagnetic ballast can also be increased because of the large electrolytic-capacitor The conventional way of supplying high intensity discharge lamps by electronic ballasts is by the application of low-frequency square waveform(LFSW) current in order to avoid the acoustic resonance(AR) phenomenon ,. These electronic ballasts mainly consists of three power stages: power factor correction, lamp power control provided by a dc–dc converter, and inverter stage. Moreover, any of these stages also require a driver which will also increase the cost of the complete system.

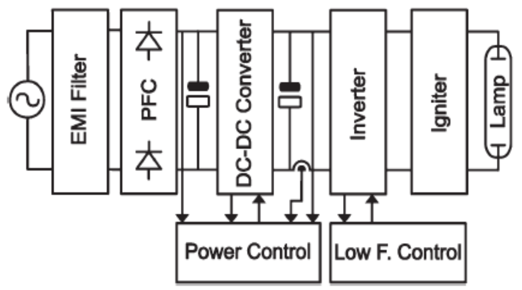

Fig. 1. Functional block diagram of classic LFSW electronic ballasts.

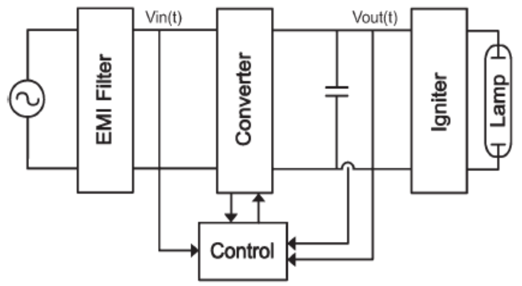

Fig. 2. Functional block diagram of ac–ac electronic ballasts.

The block diagram of classic LFSW electronic ballasts is shown in fig1.So that several efforts are being made in order to integrate the stages shown over here in the fig1 . However, and the integration of stages results in voltage or current stress in the shared switch, and these circuits need electrolytic capacitor and which will increase the cost of the circuit .This paper brings a solution for decreasing the cost of the system and to minimize the converter magnetic elements. The proposed solution to achieve this electronic ballast is by using an ac–ac converter, as shown in Fig. 2 The topologies which have the potential to achieve this goal are power ripple below the AR threshold requirement.

The proposed solution to achieve this electronic ballast is by using an ac-ac Sepic converter. Electrolytic capacitors are not using in this converter so overall cost of the system is reduced. Here we are using 70w high pressure sodium lamp as experimental example According to Dalla Costa *et al.* [3] power ripples more than 5% can cause acoustic resonance phenomena Experimental results for an HPS 70-W lamp powered from the mains (220 V • } 20% at 60 Hz) are presented for the proposed ballast. The converter is designed to operate at 33 kHz and feeding the lamp in the frequency 60 Hz, using only two controlled power switches. The controller is implemented with a 32-b/38 MIPS microcontroller.

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II. BASIC CONCEPTS

EMI filter is the first component in the block diagram .EMI means Electromagnetic interference and it is also known by the name radio interference. It is a disturbance which affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from external source. In order to reduce the electromagnetic interference we are using electromagnetic filter. Here the input current is discontinuous so EMI filter is not necessary in the input circuit. So we are not using EMI filter here in the high intensity discharge lamp circuit.

AC-AC Sepic Converter

Fig 3 shows ac-ac SEPIC converter. The single-ended primary-inductance converter (SEPIC)is a DC/DC-converter topology that provides a positive regulated output voltage from an input voltage that varies from above to below the output voltage

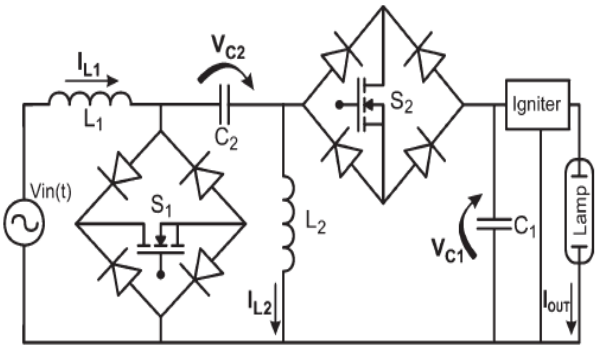

Fig 3 SEPIC Topology

The SEPIC topology is difficult to understand and requires two inductors, making the power-supply footprint quite large. Recently, several inductor manufacturers began selling off-the-shelf coupled inductors in a single package at a cost only slightly higher than that of the comparable single inductor. Here the voltage across the inductor is the output voltage peak.

During (D*Ts) S1 switch is on and then the peak input voltage is applied across the inductor L1.L2 charges capacitor C2. ducted by *S*1 charging capacitor *C*2. The instantaneous voltage on *C*2, in steady state, is the instantaneous input voltage. When *S*2 is in ON state [(1 − *D*) · *Ts*], *L*1 discharges on the circuit consisting of *C*2 and the load in parallel with *C*1. The parallel inductor *L*2 to *C*1 is submitted to the output voltage. The *L*2 current to the output of this converter is discontinuous and, because of that, requires a high output capacitor, whereas the input current is continuous, and the use of a large EMI filter to reach the electrical interference standard requirements is not necessary.

TABLE I
DESIGN PARAMETERS

Vin_{Peak}	373 V
$Vout_{Peak}$	184.2 V
D_{AVG}	0.15
$Iout_{Peak}$	1.29 A
Ripple = α	0.05
Frequency - *f*	33 kHz

III. DESIGN EXAMPLE

The ac–ac SEPIC converter was chosen in to present the design example and experimental results. The ballast must feed the HPS lamp respecting the quadrilateral diagram in Fig. 5, which shows that the minimum lamp steady-state operating voltage in 70 W is 76.5 V and the maximum is 130.2 V.Table I was defined based on the quadrilateral diagram, and it presents the worst case for not isolated electronic ballast ac–ac SEPIC design.

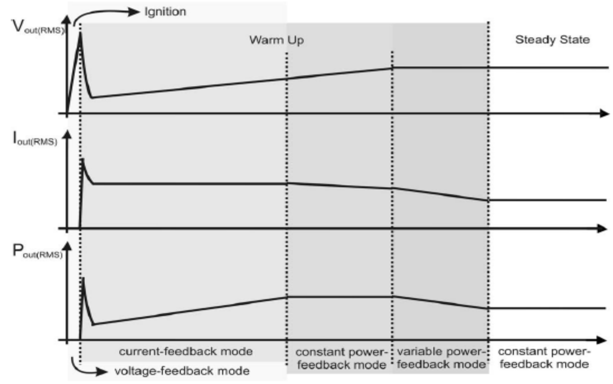

Fig. 4. Control phases [17].

The current ripple in the inductors must be minimized, thus to reduce the capacitor size. The buck–boost and SEPIC converters are the circuits that impose greater stresses at the output capacitor because of the output current discontinuity. The passive elements of the SEPIC converter are given by (2) and (3) based on the values presented in Table

Obtaining these values, the magnetic core required for the inductors is given by (8), shown at the bottom of the next page, where *Ku* is the window area utilization rate, which is usually around 0.8. Therefore, the missing parameters in order to design inductors *L*1 and *L*2 are the peak and rms currents, which are shown in (4)–(7), shown at the bottom of the next page. The current density *J* depends on the conductive material type applied to the winding, where copper is around 450 A/cm2 from where comes the factor 104 to convert this constant to m2.*B*max is the maximum flux density in the magnetic core without the saturation effects; it is a value specified by the manufacturer, but for commercial ferrites, it is around 0.25 T

$$C_1 = \frac{Iout_{\text{Peak}} \cdot D_{\text{AVG}}}{\alpha \cdot Vout_{\text{Peak}} \cdot f}$$

$$L_1 = L_2 = \frac{(D_{\text{AVG}} \cdot Vin_{\text{Peak}})^2}{Iout_{\text{Peak}} \cdot Vout_{\text{Peak}} \cdot f}.$$

TABLE II
LIST OF THE COMPONENTS FOR THE SEPIC CONVERTER

Polyester Capacitor - C_1, C_2	0.68 µF / 400 V
Ferrite Core - L_1, L_2	1.4 mH
Thornton® Ferrite Core for L_1 and L_2	Double NEE-30/15/14 –IP12E
Switch S_1	IRG4BC20UD
Switch S_2	SPA06N60C3
Diodes	MUR460
D_{max}	0.9
Resistor - Ri	1.2 kΩ - ¼W
Polyester Capacitor - Ci	47 nF/400 V
n – igniter (90/9 turns)	10

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Switch *S1* uses insulated-gate bipolar transistor technology, and switch *S2* uses the Cool MOS technology. It is performed to improve the converter efficiency because of the reason the rms current through *S*2 is much higher than that in *S*1.The SEPIC converter components are listed above in Table II

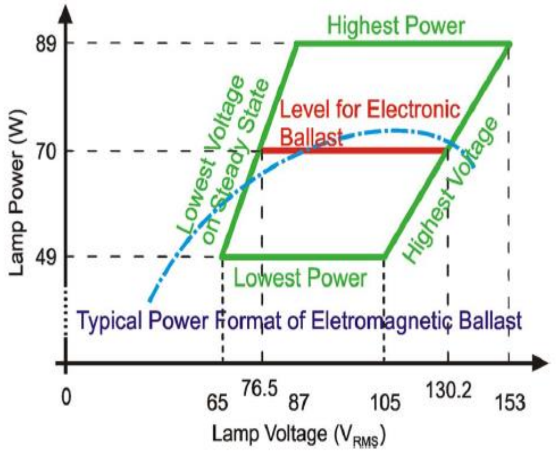

Fig. 5. Quadrilateral diagram for a 70-W HPS lamp.

IV. IGNITER CIRCUIT

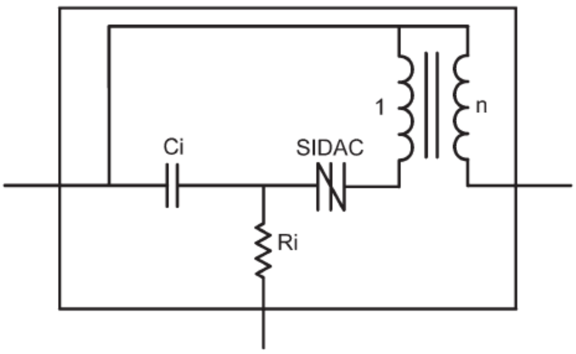

Fig.6 Igniter circuit

High-intensity discharge lamps (HID lamps) are a type of electrical gas discharge lamp which produces light by means of an electric arc between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube. This tube is filled with both gas and metal salts. The gas facilitates the arc's initial strike. Once the arc is started, it heats and evaporates the metal salts forming a plasma, which greatly increases the intensity of light produced by the arc and reduces its power consumption. High-intensity discharge lamps are a type of arc lamp. In order to ignite the lamp we are using inginter circuit which is made up of capacitors inductors and transformer

In the next sections, the proposed strategy to supply the lamp during all operational stages (ignition, warm-up, and steady state) provided by the proposed topologies is presented

A. Lamp Ignition

Previous to ignition, the converter must charge rapidly the capacitor (*Ci*), through the resistor (*Ri*), to reach the SIDAC (silicon bilateral voltage-triggered switch) breakdown voltage. During the SIDAC triggered instant, the capacitor voltage is applied to the transformer primary winding, which applies 1.8–2.5 kV at the HPS lamp, through its secondary winding. The energy stored in *Ci* is discharged on the lamp. The SIDAC semiconductor returns to blocking state, and the transformer primary current is null

B. Lamp Warm-Up

After the ignition, the lamp equivalent impedance decreases to a value around 10% of the steady-state impedance value. The proper design of the igniter inductance, discharging the energy accumulated on capacitor *Ci*, must limit the current during the ignition in 200% of the rated current. Therefore, there are not more electrode detritions at this step. During the lamp heating phase, the ballast keeps the current in below twice the nominal current until the lamp power reaches 150% of the nominal power. The output voltage should be monitored so that, when reaching the minimum voltage given by the standard EN60662 and NBR IEC 662 quadrilateral diagram in Fig. 5, the power is reduced is to nominal. Then, the steady state takes place

C. Lamp Steady State

Fig. 5 shows the required characteristics of a lamp supply during steady state. During the lamp aging, its operating voltage is being enhanced by the electrode deteriorations. Furthermore, if the lamp voltage reaches the upper limit, the ballast must be turned off In steady state, the lamp current presents a sinusoidal pattern, and the lamp voltage is close to a square waveform. Moreover, during the lamp supply zero crossing, the arc is extinguished, causing reignition and light flicker. Therefore, the proposed topologies must increase the lamp power delivering during the zero crossing in order to minimize the drawbacks of low frequency ac supply.

V. EXPERIMENTAL RESULTS & CONCLUSION

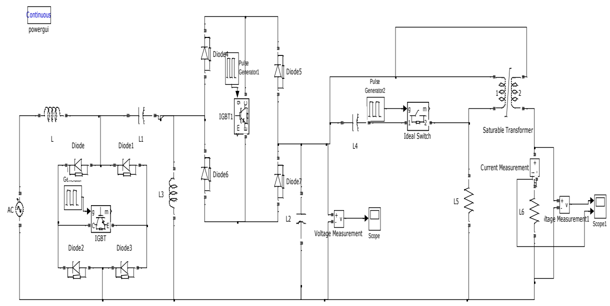

Fig.6 Simulink diagram for HID electronic ballast based on SEPIC

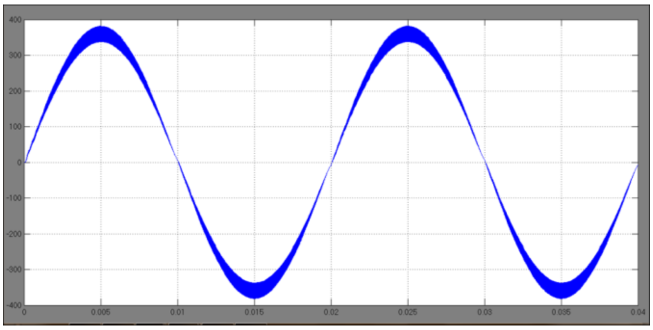

Fig.7 Output voltage across SEPIC converter

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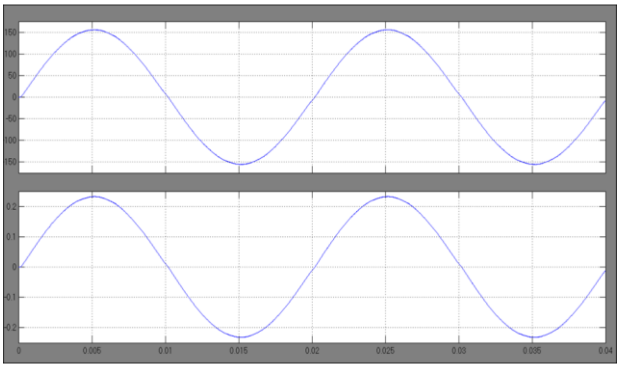

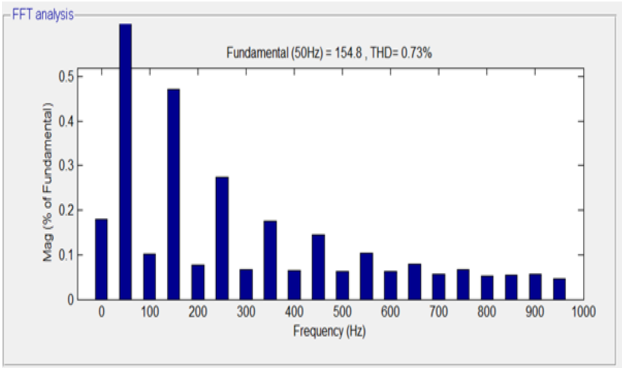

Fig8 Output voltage and current across the lamp

After the experimental setup we got the output voltage across the SEPIC converter is a sinusoidal waveform (380v) and the output voltage (160v) and current (0.3) across the lamp is sinusoidal THD is 0.73%

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