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Simplified HID Lamp Supply Using Fly-back Converter with High PF and Efficiency

G.MOHANAMBAL[1], R.YAMINI M.E[2]
PG SCHOLAR,SRI ESHWAR COLLEGE OF ENGINEERING,COIMBATORE, mohanasece@gmail.com[1]
ASSISTANT PROFESSOR, SRI ESHWAR COLLEGE OF ENGINEERING, ryamini18@gmail.com[2]

Abstract* - The HID lamps are substantially more efficacious at engendering the visible elucidation for a tending quantity of electrical power than fluorescent lamps. A pauperism of the High Intensity Discharge (HID) lamps is due to its high-ranking light intensity and prolonged energy efficiency. The Electronic ballast for driving HID lamps consisting of fly back converter is developed in this paper. In fly back converters dc supply is switched at very high frequency and inductively transferred to dc load via a high frequency transformer and rectifier. This persuasion is exploited in this paper to charge and discharge two capacitors disjunctively using two power switches colligated to primary and secondary of a high frequency transformer. In addition EMI filter (Electromagnetic Interference Filter) can be appended to preclude the interference of generated high frequency with 50Hz supply. PF, Power and Efficiency calculations are also performed. Closed loop PID control is also provided to achieve the desired output voltage.

***Keywords*- Feedback, Flyback, filter, rectifier, controller, HID lamp.**

I. INTRODUCTION

High-Intensity discharge (HID) lamps are currently widely used due to their known advantages over other lighting sources in several applications. Among the advantages, long lifetime and high luminous efficiency, achieving more than 100 lm/W, are two important characteristics. It is well-known that lighting represents a major component of energy consumption worldwide. Around 19% of global power consumption and 3% of global oil demand is attributable to lighting. In 1879, Creativity of the Edison electric light bulb was invented. Since then, many significant energy-saving lighting products have been invented. Today there are nearly 6,000 different kinds of lamps being manufactured, most of which can be placed in the following three categories: incandescent lamp, gas discharge lamp, and light-emitting diode (LED).

Incandescent lamps, gas discharge lamps and LEDs generate light through different physical Mechanisms of electrical energy conversion. Incandescent lamps based on the Joule-heating process .In these process electrically heating high-resistance tungsten filaments which produce intense brightness. The lamp current is determined by the applied voltage and the resistance of the tungsten filament, which is close to the v-i characteristic of a linear resistor. The amount energy radiated from incandescent lamps spectrum is continuous with color rendering However, incandescent lamps usually have low efficiency and only around 10% of the electrical energy flowing through incandescent lamps is converted to light. The Gas-discharge lamp produces light by passing an electrical discharge through an ionized gas. i.e. plasma. Typically, such lamps are filled with both noble gases and metals, such as mercury, sodium, and/or metal halides. Then, the metals produce the light once they are heated to a point. During process the gas is ionized and free electrons, accelerated because of electrical field in the tube, where the gas and metal atoms collide with each other. Few electrons circling around the gas and metal atoms are activated by these collisions; carry them to a higher energy state. While the electrons come back to the original state it emits a photon which produces an ultraviolet radiation or visible light. Ultraviolet radiation is converted to visible light by a fluorescent coating on the inside of the lamp's glass surface for some lamp types. An LED is a semiconductor diode that emits light when an electric current is applied in the forward direction due to the effect of electroluminescence the p-n junction emits incoherent and narrow-spectrum light. An LED is usually a small-area light source of less than 1 mm2, often with optics added to the chip to shape its radiation pattern and assist in reflection. The color of the emitted light depends on the semiconducting material which we used, and it can be infrared, visible, or ultraviolet. LEDs are widely used as indicator lights on electronic devices and increasingly in higher-power applications like flashlights and area lighting. Because individual LEDs are low-voltage DC devices, operating from AC mains requires well-designed circuitry and a thermal case to dissipate the heat.

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Common characteristics used to evaluate lamp quality include luminous efficacy, typical lamp life, and color rendering index. Luminous efficacy is the most important property of light sources, which indicates the fraction of electromagnetic power which is useful for illumination. It is the ratio of emitted luminous flux to radiant flux, and is measured by lumens per watt (lm/W). Light with wavelengths outside the visible spectrum reduces luminous efficacy, because the light with non visible wavelengths contributes to the radiant flux, while the luminous flux of this light is zero. Typical lamp life is the number of hours it takes for approximately 50% of a large group of lamps of the same kind to fail. If the lamp fails to work there is no longer light the color rendering index (CRI) is a quantitative measure of the ability of a light source to reproduce the colors of various objects faithfully in comparison with an ideal or natural light source. Incandescent lamp depends on the Black body radiation of CRI 100. CRI is expressed in a scale of 0 to 100. If the CRI value is 100 it produces visible light whereas CRI value zero there is no emission of light.

II. HID LAMP OPERATION

HPS lamps were introduced in 1968 .High pressure sodium (HPS) lamps belongs to the high intensity discharge (HID) lamp family it is more efficient white light source commercially used nowadays .The applications of HPS are as energy efficient sources for exterior, security , industrial lighting applications, and are particularly used in street lighting. Because of their high efficiency and long life it is used for many interior applications.

In a high pressure sodium lamp, a compact arc tube contains a mixture of xenon, sodium and mercury. The xenon gas is easily ionized when voltage is applied across the electrodes it facilitates striking and produces an arc. The heat generated by the arc then vaporizes the mercury and sodium. The mercury vapor increases the gas pressure and operating voltage and the sodium vapor produces light when the pressure within the arc tube is sufficient. High pressure sodium lamps are the most efficient artificial white light source with about 29% of the energy used by the lamp producing light

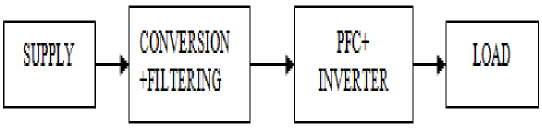

Fig 1: Basic Structure of HID Electronic Lamp

III. HIGH-PRESSURE SODIUM LAMPS

High-pressure sodium (HPS) lamps are smaller and also it contains additional elements such as mercury, it produce a dark pink glow during its first struck , while warming it produces intense pinkish orange light. Some bulbs produce a bluish white light in between if the mercury attains a high pressure arc discharge characteristic before the sodium is completely warmed. In HPS lamp sodium D-line is the main source of light and it is extreme pressure broadened. According to the broadening and emissions from mercury, more colors can be imposed compared to a low-pressure sodium lamp. It is used to areas where improved color rendering is desired. Thus, its new model name SON is the version for "sun" (a name used primarily in Europe and the UK). HPS Lamps are preferred by indoor gardeners for general growing because of the wide color-temperature spectrum produced and it is relatively efficient cost of running the lights.

High pressure sodium lamps are efficient the range of 100 lm/W where it is measured by photopic lighting conditions. The higher powered edition of 600 W which have an efficiency of 150 lm/W. It can be widely used for outdoor area lighting such as streetlights and security. The perceptive of human color vision sensitivity from photopic to mesopic and scotopic is necessary for proper planning when designing lighting for roads. Due to this extremely high chemical activity of the high pressure sodium arc, the arc tube is made up of translucent aluminum oxide. This structure led General Electric to use the trade name "Lucalox" for their line of high-pressure sodium lamps.

Xenon is a low pressure gas it can be used as a "starter gas" in the HPS lamp. Where as it has the lowest thermal conductivity and lowest ionization potential of all the non-radioactive noble gases. The noble gas does not

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interfere with the chemical reactions take place in the operating lamp. While in operating state the low thermal conductivity minimizes thermal losses in the lamp , and the low ionization potential can stimulate the breakdown voltage of the gas it relatively low in the cold state, which allows the lamp to be start easily.
Electronic switch-mode DC-to-DC converters convert one DC voltage to another voltage level, while storing the input energy temporarily and then releasing energy to the output at a different voltage. The storage may be magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). This conversion method is efficient (often 75% to 98%) compared to linear voltage regulation (which dissipates unwanted power as heat). This efficiency is beneficial to raise the running time of battery operating devices. Due to the use of power FETs the efficiency has increased since 1980s, which are capable to switch at high frequency more efficiently than power bipolar transistors, which it is obtain more switching losses and require a more complicated drive circuit. Another important design in DC-to-DC converters is the use of synchronous rectification replacing the flywheel diode with a power FET with low "On" resistance, thereby decreasing switching losses.

The Most DC-to-DC converters are designed to travel power in only one direction, from the input to the output. All switching regulator topologies can be made bi-directional by replacing all diodes with independently controlled active rectification. A bi-directional converter can propel the power in both directions. It is useful in applications requiring regenerative braking. Switching converters have few drawbacks it include complexity, electronic noise (EMI / RFI) and some stage cost, although this can reduced in advances chip design. The integrated circuits had a DC-to-DC converters which is minimal additional components and also Hybrid circuit contains DC-to-DC converters which is readily available within electronic assembly

Regardless of the advantages of HID lamps as high-quality lighting sources, the utilization of HID lamps in low-power application are limited by the high initial cost of both lamps and ballasts. HID lamps are rarely used in residential applications. To take track lighting as an example; the major two competitors in this application are halogen lamps and HID lamps. HID lamps have much higher luminous efficacy (one 20W HID lamp can provide the same lumens as one 70W halogen lamp), and much longer lamp life time (up to 12000 Hours) than a halogen lamp (up to 4000 Hours). However, HID lamps make up less than 20% of the total market for track lighting, while halogen lamps make up around 70% of the market. The major reason for this is that halogen lamps are basically incandescent lamps, so they don't need ballasts, while HID lamps need expensive ballasts, and additional space is needed for the ballast. It takes around four years for the energy savings and lower maintenance costs of an HID lamp to offset the high initial cost. Therefore, developing cost-effective, high density electronic ballasts with high performance by using advanced high-frequency electronic ballasting techniques is the key to promoting the utilization of HID lamps.

IV. FLYBACK CONVERTER TOPOLOGY

Fly-back converter is the nowadays normally used SMPS circuit for low output power applications where the output voltage inevitably to be isolated from the input main supply. The response of this type of circuit may vary from few watts to less than 100 watts.
The overall circuit topology of this converter is substantially simpler than the other SMPS circuits. Input of the circuit is generally unregulated dc voltage incur by rectifying the utility ac voltage followed by a simple capacitor filter. The circuit can propose a single or multiple isolated output voltages and can be operate over a wide range of input voltage variation. The respective energy-efficiency, fly-back power provision are subscript to other SMPS circuits but it is simple topology and low cost makes it favorite in low output power range.

A. OPERATION STAGES OF FLYBACK CONVERTER

The basic functional principle of the proposed dc–ac fly back is based upon the application of the voltage difference between capacitor C1 and C2 to the lamp. The converter consists of a bidirectional fly back working at high frequency, where the energy flows in both directions at a low frequency manner,
Stage1: In stage1, where C2 voltage is the sum of E and the load voltages, reverse biasing (blocking) D4. S1 conducts and S2 remains opened. C1 voltage is applied to the fly back primary, N1. Thus, primary is charged with energy squarely proportional to the current through S1, supplied from C1.

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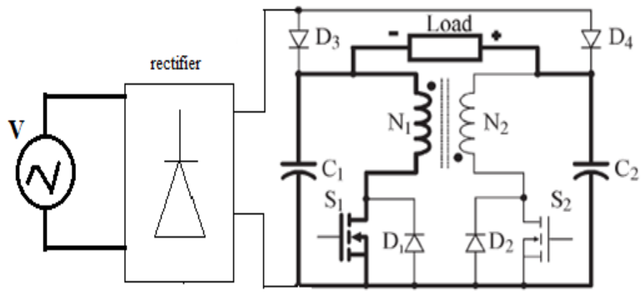

Fig 2: Operation Of stage 1

Stage 2: In stage2, When C1 voltage is equal to the voltage of the input voltage source E (C2 remaining with lamp plus E voltages), still with S1 closed and S2 opened, voltage E is directly applied to the fly back primary N1. Choke continues to be charged, but with the energy from the voltage source E.

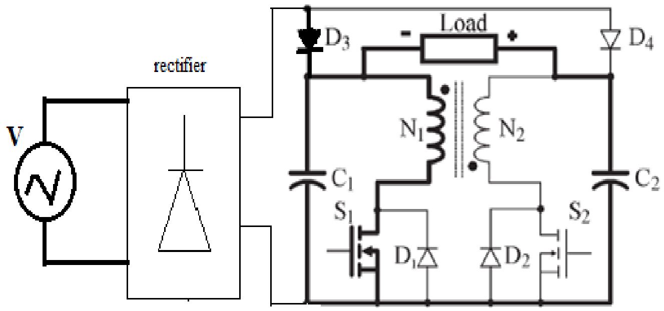

Fig 3: Operation Of stage 2

Stage 3: S1 is opened. The energy stored in the magnetic core is transferred to the capacitor C2 through current flowing by the anti-parallel diode of S2, D2.

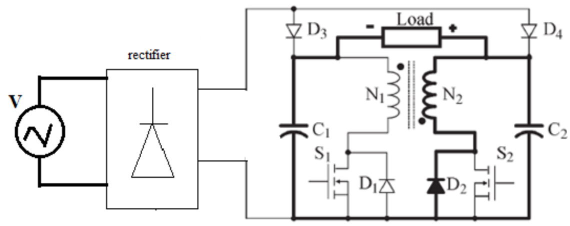

Fig 4: Operation Of stage 3

Stage 4: S1 and S2 are kept off and there is no energy stored in the choke. Current flows from C2 to C1 through the load.

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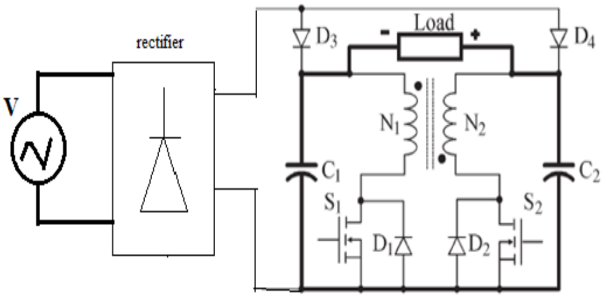

Fig 5: Operation Of stage 4

V. SYSTEM ANALYSIS

A. POWER MOSFET

The Metal-Oxide-Semiconductor-Field-Effect-Transistor (MOSFET) is a semiconductor device controllable by the gate signal (g > 0) if its current Id is positive (Id>0). The MOSFET device is connected in parallel with an internal diode which turns on when the MOSFET device is reverse biased (Vds < 0). The model is simulated as a series combination of a variable resistor (Rt) and inductor (Lon) in series with a switch controlled by a logical signal (G>0 or g=0).

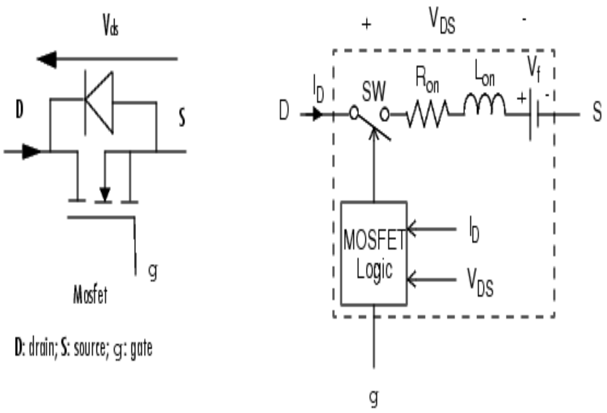

Fig 6: Basic MOSFET Structure

The MOSFET switch is turns on when the drain-source voltage (Vds) is positive and a positive signal is applied at the gate input (g >0) with a positive current flowing through the device, the MOSFET switch turns off when the gate input becomes zero. If the current Id is negative (Id flowing in the internal diode) and without a gate signal (g = 0), the MOSFET turns off when the current Id becomes zero (Id = 0).

Now note that the on-state resistance Rt based on the drain current direction:

•Rt= Ron if Id > 0, where Ron refers the typical value of the forward conducting resistance of the MOSFET device.

•Rt= Rd if Id < 0, where Rd refers the internal diode resistance

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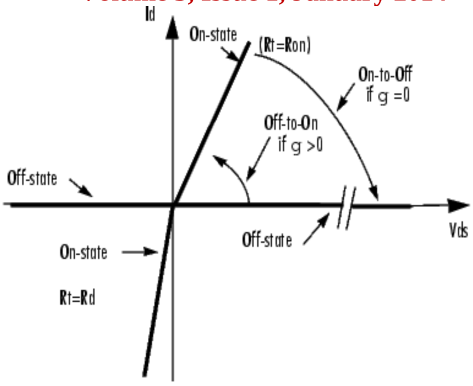

Fig 7: Power MOSFET Operating state

B. CONTROLLER

The closed loop PID controller is provided to achieve the desired output voltage. A proportional–integral–derivative controller (PID controller) is a generic control loop feedback concept commonly used in industrial control systems. A PID is the mostly used feedback controller.

A PID controller calculates an "error" value as the compared between a measured process variable and a desired set point. The controller initiates to reduce the error by varying the process control inputs.

The PID controller measurement involves three separate constant parameters values, and it is sometimes called the three-term controller: the proportional, the integral and derivative values P based on the present error value, I on the aggregation of previous errors, and D is a forecasting of upcoming errors, depends on current rate of change. The weighted sum of these three functions is used to varying the process through a control element such as the position of a control valve, or the power applied to a heating element.

C.BRIDGE RECTIFIER

The bridge rectifier which is used to convert the ac signal to dc signal .The Universal Bridge block implemented as a three-phase power converter that contains a up to six power switches connected in a bridge configuration. These types of switch and converter is suitable for the proposed system. The Universal Bridge block allows simulation of converters using both naturally commutated (or line-commutated) power electronic devices (diodes or thyristors) and forced-commutated devices (GTO, IGBT, MOSFET).The Universal Bridge block is the basic block for building two-level voltage-sourced converters (VSC).The device numbering is different if the power electronic devices are naturally commutated or forced-commutated.

VI. SIMULATION RESULTS

In the proposed system, the dc supply can be obtained by rectifying the standard 230V, 50Hz AC supply. So that the converter can be directly operated from standard ac supply. In addition EMI filter can be added to prevent the interference of generated high frequency with 50Hz supply. The Power Factor, Power and Efficiency calculations are also performed for the design. The advantages of the proposed system are additional power devices and passive components are not required.ZVS is achieved at resonance. Switching losses, conduction losses are reduced and highly Efficient.

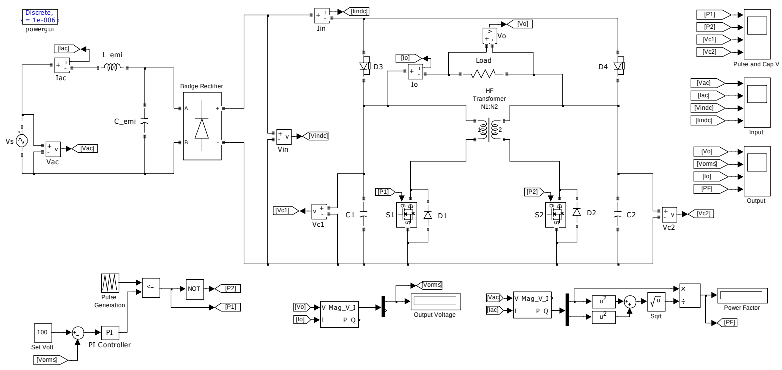

Fig 8: Simulation Diagram for Proposed System

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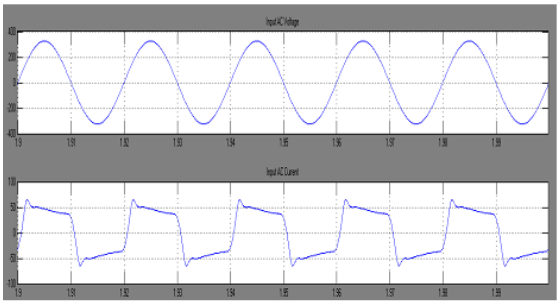
Flyback has been proposed for low power HID lamps supply, keeping reasonable efficiencies while providing the required current control and inversion with reduced switch number, still one magnetic core, however two capacitors as output filters instead of one. Another advantage is their potential for integration of PC and PFC stages by sharing their active switches.

Input AC Voltage and Current



Pulses to MOSFET Switches S1-S2

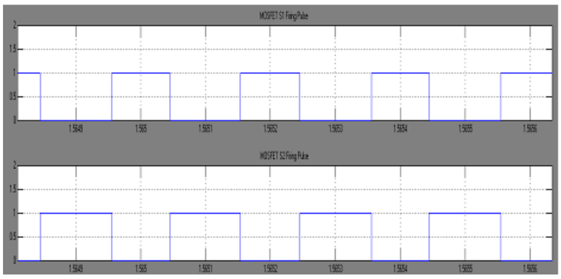
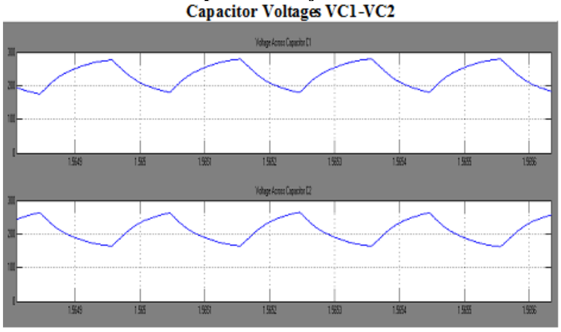


Fig 9: Input Ac Voltage 230V with Frequency=50HZ. And Triggering Signal for MOSFET with Voltage=3.5V Complementary MOSFET

Capacitor Voltages VC1-VC2



Output AC Voltage and Current

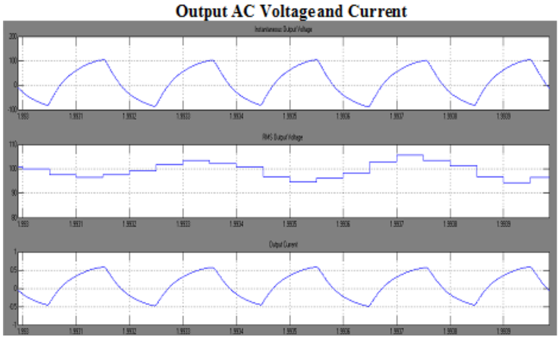


Fig 10: Shows Voltage across Capacitor C1 and Capacitor C2. The Output Ac Voltage, RMS and Output Current.

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Power Factor

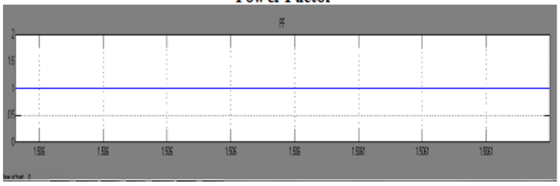

Fig 11: shows the unity power factor, the power factor can be achieved by closed loop system

VII. CONCLUSION

Efficiency is the main factor for lamp applications; hence it reduces the power consumption and also increases the reliability of the output power. A simulation result has been obtained to verify the analytical results previously presented. The Electronic ballast for impulsive a HID lamps with high frequency from a 230 main supply. The converter model has been presented; in add-on the filter circuit utilized in order to reduce the undesirable noise signals. A high intensity discharge lamp (Sodium Lamp) using the concept of fly back converters is formulated with high power factor and efficiency. The simulation results can be achieved with feedback system. EMI filter (Electromagnetic Interference Filter) is added to prevent the interference of generated high frequency with 50Hz supply. The resultant of this paper shows that envelope simulation can be used to incur the small signal response of a high frequency system. The validity of the acquaint simulation method was proven and exhibit simulation tool is reliable and simple to use. It is thus concluded that by applying proposed simulation and design methodology, one can improve the PF and performance by operating the system in closed loop configuration so the power factor is improved at 0.998 and the efficiency 88%. Current efforts are focused to improve the efficacy by reducing the power losses between the active and passive devices.

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