Abstract – In the recent years many authors [1-4] are working to obtain single stage HPF electronic ballast for fluorescent and HID lamps to obtain cost reduction and to comply with international standard requirements. Usually to obtain HPF in electronic ballast for high pressure sodium lamps a Power Factor Preregulator (PFP) is used between the mains and the electronic ballast [5]. In this paper will be reported the study and implementation of two single stage high power factor (HPF) electronic ballasts for high pressure sodium (HPS) lamps using a LCC filter, one using a half-bridge inverter and the second one using a full-bridge inverter. The main idea in this work is to compare two simple electronic ballasts topologies with HPF for HPS lamps working with a 220 V_{RMS} mains voltage. Design criteria, simulation and experimental results will be also presented for a full bridge inverter in the final paper.

I. INTRODUCTION

Nowadays, an important topic of awareness is the importance of environment preservation. In this direction, important efforts have been made in the diverse areas of knowledge. In electrical engineering field, this phenomenon has reflected in searching for alternatives energy systems, higher efficiency on available resources utilization, losses reduction in equipments and to increase electric energy quality.

In the last few years the market was flooded by a great number of electronic ballasts for fluorescent lamps operating in high frequency, especially by compact fluorescent lamps. Its utilization was widely stimulated by Brazilian media for energy economy, due the fact that luminous efficiency increases with the frequency for this kind of lamp. Brazil faced a serious energy crisis in 2001. Many corrective actions were taken to mitigate this serious problem. One of them was the energy rationing which consisted in overtaxing or even cutting energy supply from consumers which exceeds the prefixed energy quotes. Also many electric energy concessionaires had distributed gratuitously compact fluorescent lamps for residential consumers, showing the importance of illumination’s segment inside the global energy consumption, estimated to be about thirty percent of total consumption of electrical energy in the country. Because of these, innumerable research groups around the world, like [1-8], have dedicated their efforts to the development of new topologies and new control techniques for different kinds of discharge lamps.

Most of magnetic ballast manufacturers had to develop electronic ballasts for discharge lamps to guarantee their survival in business because the consumers started to demand more and more this type of product. It also simplifies the production line, which has expressive physical reduction and productivity increase in relation the line that produces the conventional ballasts. Now, the challenges for industries are the reduction of production costs, the reduction of converter size, unitary power factor and null harmonic distortion which implies in a substantial improvement of energy quality consumed by ballasts. In Brazil, the development of electronic ballasts for HID lamps is being made by a few groups of researchers. However in a close future, these ballasts will be in the production lines of main national manufacturers.

The porpoise of this paper is to report the development of two low cost single stage HPF electronic ballasts for HPS lamps for a 220 V_{RMS} mains voltage. Each ballast was implemented using a different inverter topology. The design criteria will be presented in this work for the proposed circuits.

There are many kind of high intensity discharge lamps; however, this work will focus only the high-pressure sodium lamps (HPS), widely used in public illumination. The HPS lamps radiate energy on a great part of the visible spectrum. Those lamps provide a reasonable color reproduction (it has IRC 23 color reproduction index). They are available up to 130 lm/W of luminous efficiency and color temperature of 2100 K, approximately.

The HPS lamps, as any other HID lamps, need ballast to operate correctly. The ballast is an additional equipment connected between the power line and the discharge lamp. The ballast has two main functions: to guarantee lamps ignition through the application of a high voltage pulse between the lamp electrodes and to limit the current that will circulate through it. The lamp would be quickly destroyed without current limitation, due the negative resistance characteristic of the lamp, as can be observed in figure 1.

![Fig. 1. - Typical voltage versus current curve for HID lamps.](image)

In order to obtain low cost electronic ballast for HPS lamps with HPF a single stage converter was conceived. The idea is very simple: Once, in high frequency, the HPS lamps have a resistive behavior, why the electronic ballast (inverter and LCC filter) can not be connected directly to a full bridge rectifier? This idea will be discussed in this paper.
In [9] it was studied the possibility of using this concept with a half bridge (HB) inverter. Unfortunately, for a 220 V$_{\text{RMS}}$ mains, this topology is not indicated as it will be demonstrated in this paper. In another moment it was proposed, by the some authors, the implementation of this concept with a full bridge (FB) inverter. The utilization of these topologies will be discussed in this paper.

II. STUDIED ELECTRONIC BALLASTS

The studied single stage high power factor electronic ballast for high pressure sodium lamps structure incorporates a bridge rectifier and an input LC filter to minimize the EMI generated by the electronic ballast. Two inverters topologies were proposed to operate with this concept of avoiding the utilization of an external PFP.

Figure 2 shows the electrical diagram of the first proposed circuit. In this circuit was used a half bridge inverter connected to the LCC filter. Similar circuits have been proposed by other authors using fluorescent lamps. But any paper using this topology for HPS lamps was not found. The capacitor $C_F$ in this figure has two main functions first of all is to receive the reactive current from the electronic ballast and work as line filter with the inductor $L$. This arrangement provides high power factor to the electronic ballast because in this case the capacitor $C_F$ is not a bulk capacitor. Actually this is a small capacitor in the range of nano Faradays.

Fig. 2. Studied Half Bridge HPF Electronic Ballast.

The second electronic ballast studied used a full bridge inverter topology as showed in figure 3. The input stage of this topology has the same characteristic as the topology presented on figure 1. The main difference between HB and FB topologies is the available RMS voltage applied to the LCC filter.

Fig. 3. Studied Full Bridge HPF Electronic Ballast.

III. SIMULATION RESULTS

To validate the proposed system, a full-bridge electronic ballast with the following specification: 250 W HPS lamp, 220 V$_{\text{AC}}$ grid connected and operation frequency of 68 kHz, was simulated using the software PSIM® 6.0. The voltage in the lamp, after ignition, is showed in figure 6.

Figure 7 shows the lamp voltage, the voltage and current in the mains. The crest factor was measured. It was found a crest factor of 2 using this ballast.

Fig. 4. Voltage in the lamp after ignition.

Fig. 5. Above, voltage in the lamp and voltage and current in the mains below.

IV. EXPERIMENTAL RESULTS

The Half Bridge ballast was implemented. The values of used resonant elements was obtained and its values are $L = 220 \mu$H, $C_s=55$ nF witch was implemented with five 11 nF capacitors in parallel and $C_p = 2.73$ nF witch was implemented with three 8.2 nF capacitors in series. In figure 8, voltage and current in the mains are showed.

Fig. 6. Voltage and current in the mains.

In figure 9 is showed the lamp’s voltage and current. It could be observed that next to each zero crossing the lamp is turned off and on, as well as it happens with usual
ballasts. This phenomenon is attributed to the lamps non linear characteristic and it was not considered in the simulation model.

![Image](image_url)

Fig. 7. Voltage and current in the lamp in low frequency.

V. CONCLUSION

The half bridge topology will never generate the necessary voltage to achieve the lamp full rated power 250 W in a 220 V RMS mains, which impossibilities the design of these ballast in this case. On the other hand this topology is suitable for lamps less than 250 W once the main restriction is the available RMS voltage. This paper described two single stage high power factor electronic ballast for high pressure sodium lamps using a half and a full bridge inverter. It is important to remark that the proposed design criterion is valid for both converters. This ballast presents a very low cost because it avoids an external PFP.

The phenomenon of the acoustic resonance was not observed in our prototype. A very high power factor was obtained. The crest factor found was not good enough and must be improved. This could be solved changing the capacitor $C_s$ value. Increasing this capacitor is possible to reduce the crest factor, on the other hand, the power factor decreases. More experimental results will be presented in the final paper.

It will be also presented in the final paper the design criteria, the simulation results using a full model of a HPS lamp for high and low frequencies and, with the implementation of the full bridge topology, a comparison with experimental results will be also made.

VI. REFERENCES


