HIGH FREQUENCY INVERTER FOR FLUORESCENT LAMP: MODELING SIMULATION AND REGULATION

G. Lee
Fachbereich Elektrotechnik
Gesamthochschule Hagen, Germany

Abstract Two different resonance inverters used as fluorescent lamp ballast are based on the self oscillation at the series resonance of the circuit components. Each circuit is simulated on a computer in order to explain its function and the variation of the circuit variables for each of the circuit elements.Experimental results have been carried out on the unsymmetrical scheme to indicate the voltage and current of the fluorescent lamp operation at the high frequency.

INTRODUCTION

With the recent advances of power electronic devices it has become possible to save the electric energy consumption in many domains of applications. An interested domain of power electronic devices application is the electronic ballast used for fluorescent lamp/1/. Fluorescent lamps are widely used in the daily life,the save in the energy consumed per lamp leading to a great amount of energy saving.

This paper deals with the series resonance energy inverters which are charaeterized by their implementation simplicity,self controllability and high efficiency. Two proposed circuits/2/ are studied to explain the performance of this inverter type when used as a fluorscent lamp electronic ballast. The operation of this circuits is based on the self oscillation at the series resonance frequency of the circuit components. A current feedback loops are realized to supply the transistors gate current to maintain the self oscillation at the series resonance frequency of the circuit components.

INVERTER SCHEMES AND MATHEMATICAL MODEL

The description of each proposed inverter scheme can be illustrated by the circuits shown in fig.1 and 2. In fig.1 a symmetrical half bridge inverter is used with the virtual supply mid-point realized by two capacitors C_a and C_b. The inverter load is considered as the whole circuit except the transformer TRF whose impedance is negligible. Two feedback loops are realized by TRF to supply the conductivity modulated field effect transistor(COMFET) T_1 and T_2 gates and maintain the inverter operating frequency to the load circuit series resonance frequency /2/. The primary current of TRF produces the necessary voltage to drive the COMFET switch gate T_1 for the positive load current half cycle and that of T_2 for the negative load current half cyle. When T_1 is tuaned on a voltage of $E/2$ is applied to the load circuit and a voltage of $-E/2$ is not possible with the structure of TRF secondary coils. The flyback diodes D_1 and D_2 insure the alternative paths for the inductive current turn off specially at the transient periods. At the load terminals, this type of inverter structure supplies a symmetrical square wave voltage of amplitude $E/2$ and frequency equals to the load natural frequency,consider the starting case in which the fluorescent lamp is not tate behavior of the two proposed inverters circuits are the smae as it was shown in the mathematical model, it was sufficient to realize one of them. The unsymmetrical inverter was realized because it was less components than the symmetrical one ,see fig. 1 and 2. The experimental results were obtained for the unsymmetrical ballast circuit supplied from 230V main. Fig.4 shows the no load voltage and current wave forms. It can be observed that there is a good concordance between the experimental and simulation results. At loading condition the fluorscent lamp voltage and current are illustrated in fig.5. The lamp power 40W and the operating frequency is 23.8 kHz. If we consider that these current and voltage are both sinusoidal the rms voltage current are 88.4V and0.495A respectively which give 43.75W.

CONCLUSIONS

A self oscillating series resonance inverter is simulated,realized and tested for the use as a fluorescent lamp electronic ballast . This type of inverters have a high efficiency which reduces the power loss of the flourescent lamp circuit. The Mathematical model for two types of symmetrical and unsymmetrical series resonance inverters are carried out. These models give an interesting results:they have both the same steady- state and the difference in the transient is small. Therefore,it is recmmended to realize the unsymmetrical scheme which has less components than the symmetrical one. Experimental results have been carried out on the unsymmetrical scheme to indicate the voltage and current of the fluorescent lamp operation at the high frequency.

Die Eule der Minerva fliegt erst bei Nacht !!

REFERENCES

/1/ Philps Lighting:general technical manuels for HF ballasts.1990

/2/ Peter Heinrich,Armin Kröning:Elektronische Vorschaltgeräte, Licht,Heft2/März 1987

/3/ Computer programs: ETPE ,GHS Hagen,1991

/4/ Erwin Klein:Elektronische Vorschaltgeräte für Leuchtstofflampen,etz,Heft7/8,April 1988.

/5/ Krummel,P.:Private Mitteilung,1990.

/6/ Krummel,P.:Private Mitteilung(Siemens),1991.

/7/ Peter Heinrich,PeterKrummel:Vollektronische Vorschaltgeräte;Die neue Generation ist da Siemens_Elektrdienst,26.Jahrgang,Juli 1984 Heft 2,Seiten 16_18.

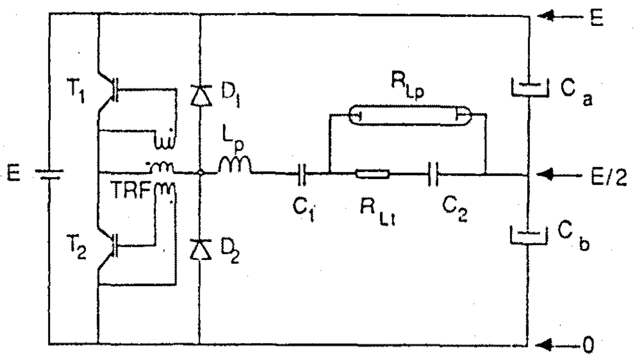


Fig.1 Symmetrical half bridge inverter

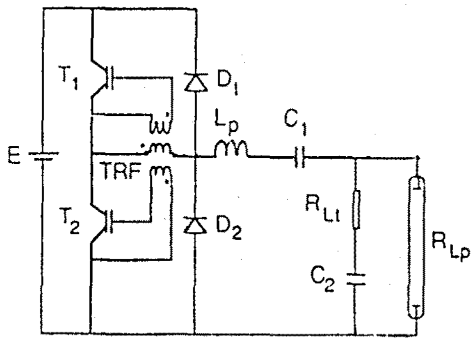


Fig.2 Unsymmetrical half bridge inverter

ignited,if the resistance R_{Lt} is zero the load current will be infinite. Therefore, the role of this resistance is to limit the circuit current to its designed value. The voltage across the series R_{Lt} and C_1 branch,in the starting case,must exceed the lamp ignition voltage, In the operating case,when the lamp is ignited, the series equivalent circuit of the parallel branches R_{Lp}-$R_{Lt}C_2$ has a very high equivalent capacitance and then it is neglected compared with C_1. Also,the $R_{Lt}C_2$ branch current is so small that it can be neglected with respect to the lamp current. The limiting resistance R_{L1} power loss is negligible both in the starting and operating case.

In fig.2 is shown the scheme of unsymmetrical half bridge inverter. The circuit description in this case is exactly the same as the symmetrical one except for the load applied voltage which varies between 0 and E. The DC source E together with the switch modules can be represented by a square wave voltage source To simplify the modeling task the load circuit is represented by its series R,L and C equivalent circuit in the starting or in the operating conditions. The driving function e(t) is a piecewise regular function its periodically 2k second,since the system is self oscillating one then $k=\pi/\omega$, $\omega=\sqrt{(1/LC)-(R/2L)^2}$ The solution,c rrent of the system differential equation in the interval

$$nk < t < (n+1)k$$

for the symmetrical inverter is

$$\begin{aligned} i(t) = &- E\, e^{-\sigma t} \sin\omega t / 2\omega L\,(e^{\sigma k} - 1) \\ &- E\, e^{-\sigma (t-k)} \sin\omega t / 2\,\omega L\,(e^{\sigma k} - 1) \\ &+ E\, e^{-\sigma (t-nk)} \sin\omega t / \omega L\,(e^{\sigma k} - 1) \qquad (1) \end{aligned}$$

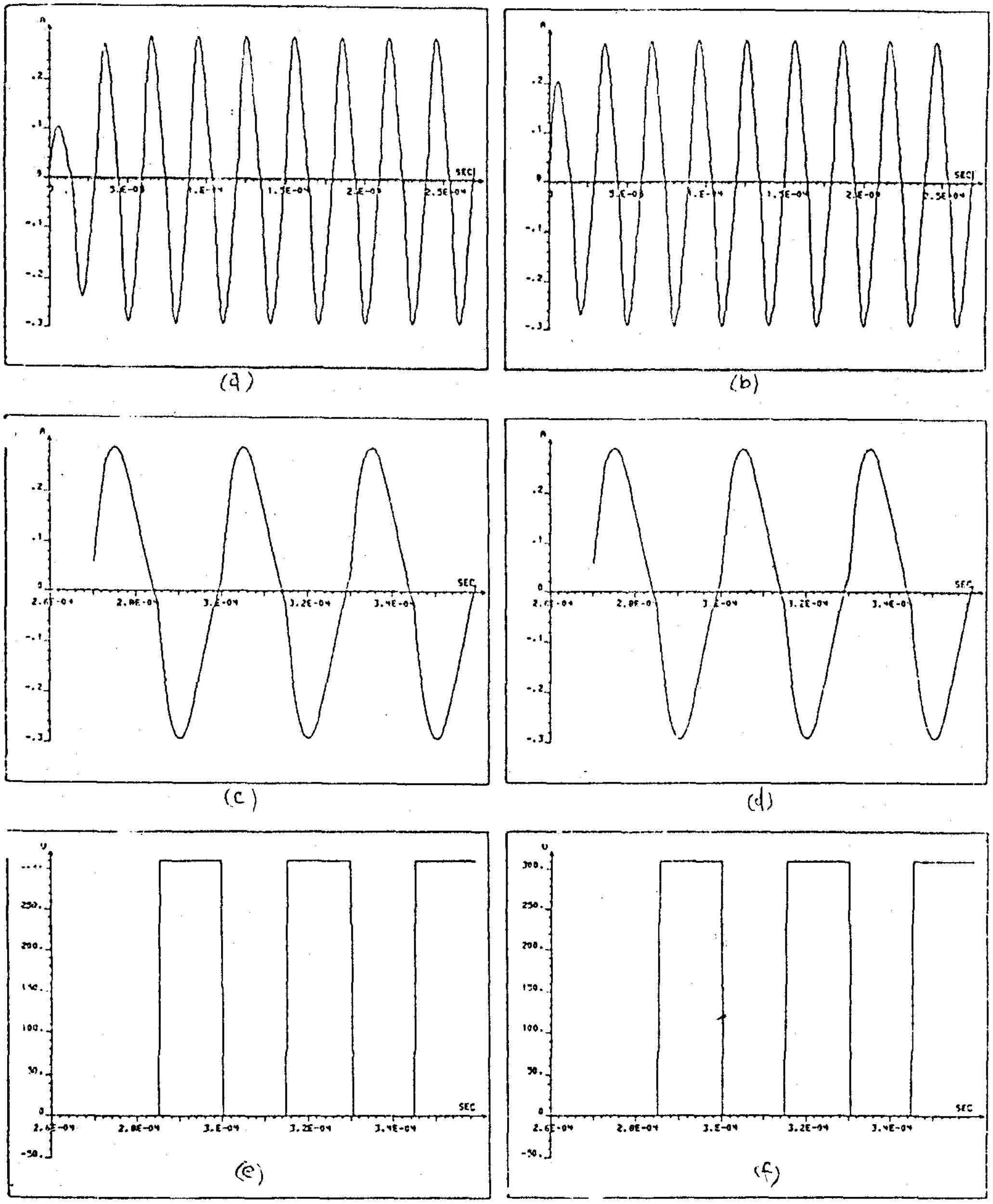
$$\sigma = R/(2L)$$

and for the unsymmetrical inverter is

$$\begin{aligned} i(t) = &- E\, e^{-\sigma t} \sin\omega t / \omega L\,(e^{\sigma k} - 1) \qquad (2) \\ &+ E\, e^{-\sigma (t-nk)} \sin\omega t / \omega L\,(e^{-\sigma k} - 1) \end{aligned}$$

In each mathematical model the first term does not depend on the interval at which the model is applied. The symmetrical circuit is 1/2 the unsymmetrical circuit current in the first half period $0<t<k$,in the second half period $k<t<2k$ the second term of equation (1) has the same value as the first term of this equation in the first half period. The second term of equation(1) does not depend on the interval at which the model id applied. Therefore,the first and second terms of equation(1) and the first term of equation (2) correspond each other, they are relative to the transient of the refered circuit and decay quickly. The third term of equation (1) and the first term of equation (2) correspond each other, they are relative to the transient of the of the refered circuit and decay quikly. The third term of equation (1) and the second term of equation (2) are exactly the same and they present the circuit steastate current. These terms include the interval dependant variable n and they are relative to the transient of the refered circuit and decay quickly. The third term of equation (1) and the second term of eq(2) include the interval dependant varible n and they have the same form during each period. The two proposed circuits have the same steady state current. The great difference in the transient appears during the first and second periods only /4/-/7/.

The two proposed inverters are simulated on a computer by a simulation program/3/. The purpose of this simulation is to indicate the difference between the two proposed circuits in both transient and steady-state conditions. The results carried out on the symmetrical half bridge are illustrated in the left column of fig.3. The results of the unsymmetrical half bridge inverter corresponding to each of the symmetrical one are shown in the right column of fig.3. The operating frequency of the circuit is 33.3 kHz for R=680 Ohms,L=4mH and C=4.5nF. The supply voltage for each circuit is 310 DCV obtained by rectifying and filtering 220 ACV. As previously explained the great difference between the two circuits response is at the first half cycle. It can be explained by the fact that the unsymmetrical circuit has a fast transient response compared with the symmetrical one fig.3. The steady-state response is the same for both circuits shown in fig3 (c and d). The switched elements of each must support the same voltage as illustrated in fig.3(e and f). Since the steady-



(a) (b)

(c) (d)

(e) (f)

Fig.3 Transient and steady_state response of symmetrical and unsymmetrical inverters

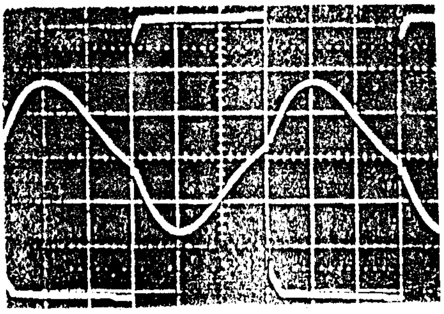


Fig.4 Noload voltage and current wave forms

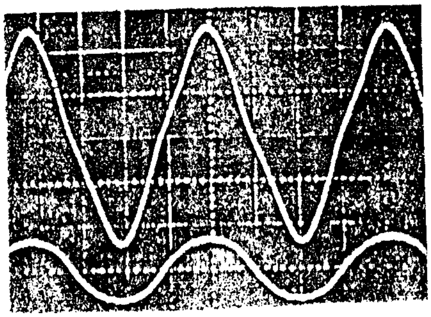


Fig. 5 Voltage and current of the ignited fluorescent lamp