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Weak Periodic Perturbation method applied to control chaos in positive output Luo converter

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Abstract: Chaos is a non-linear phenomenon found in all non-linear systems. The dc-dc converters exhibit wide range of bifurcation and chaotic behaviour under certain operating conditions. The weak periodic perturbation (WPP) method is introduced to control the chaos in positive output Luo converter. In this paper, WPP is applied to stabilize an unstable orbit of a chaotically operating current controlled positive output Luo converter and to operate in stable region. The simulations using MATLAB/ SIMULINK shows that the operating region is extended by weak periodic perturbation method.

Keywords: Positive Luo converter, Current controlled mode, Chaos, Weak periodic signal.

I. INTRODUCTION

The basic dc- dc converters are widely used in many industrial applications to get the variable dc voltage from a fixed DC source. The different types of advanced converters are used in all industries and also in computer hardware applications. These advanced converters can provide both step-up and step- down operation. The switching of power converters exhibits a non-linear behaviour like period of doubling and chaos, when some of the system parameter varies. This non-linear behaviour reflects in the converter operation in terms of undesired output.

In section II, basic operation and waveforms of the positive output Luo converter have been explained. In section III, Current controlled positive output Luo converter is presented to analyse the period of doubling and chaotic behaviour. In section IV, weak periodic perturbation method is applied to control the chaos in positive output Luo converter.

II. POSITIVE OUTPUT LUO CONVERTER

The power circuit diagram of the positive output Luo converter is shown in figure.1. The positive output Luo converter offers the flexibility of providing both low and high positive polarity dc voltage than the supply voltage.

In this circuit, the switch S is realized using MOSFET with the frequency F_s. It consists of the freewheeling diode (D), two inductors (L_1, L_2), two capacitors (C_1, C_2) and the load resistance(R).

There are two modes of operation namely Mode I and Mode II.

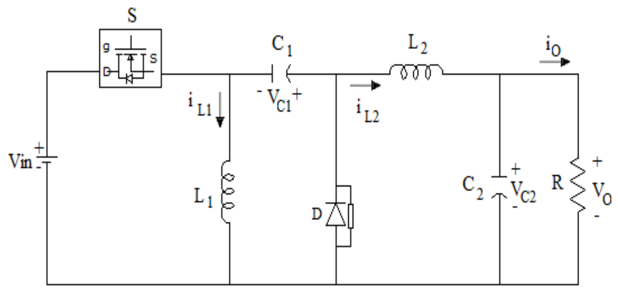

Figure 1. Power circuit diagram of positive output Luo converter

A. *Mode I Operation*

The equivalent circuit of Mode I operation is shown in figure 2. When the switch S is turned ON, the inductor L_1 gets charging and inductor current increases from i_{L1} to i_{L2}. At the same time, the load is supplied by I_o through the inductor L_2 due to the discharging of the capacitor C_1.

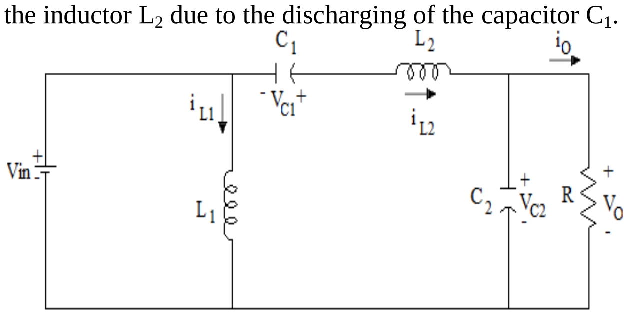

Figure 2. Equivalent circuit of positive output Luo converter in mode I operation

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The equations governing the circuit dynamics under mode I operation are as follows,

$$\frac{di_{L1}}{dt} = \frac{E}{L_1}$$

$$\frac{di_{L2}}{dt} = \frac{E - V_{c1} - V_{c2}}{L_2}$$

$$\frac{dV_{c1}}{dt} = -\frac{i_{L2}}{C_1}$$

$$\frac{dV_{c2}}{dt} = \frac{i_{L2}}{C_2} - \frac{V_{C2}}{RC_2}$$

B. *Mode II operation*

The equivalent circuit of Mode II operation is shown in figure 3. When the switch S is turned OFF, the capacitor C_1 gets charging from the inductor L_1 and the current decreases from i_{L2} to i_{L1}. The energy stored in the inductor L_2 is now transferred to the capacitor C_2 through the freewheeling diode (D) and the load receives the current I_o.

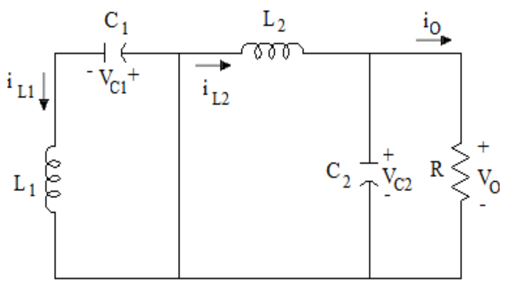

Figure 3. Equivalent circuit of positive output Luo converter in mode II operation

The equations governing the circuit dynamics under mode II operation are as follows,

$$\frac{di_{L1}}{dt} = \frac{-V_{C1}}{L_1}$$

$$\frac{di_{L2}}{dt} = \frac{-V_{c2}}{L_2}$$

$$\frac{dV_{c1}}{dt} = \frac{i_{L1}}{C_1}$$

$$\frac{dV_{c2}}{dt} = \frac{i_{L2}}{C_2} - \frac{V_{C2}}{RC_2}$$

The theoretical waveforms of switch voltage (V_s), diode current (i_D), inductor currents (i_{L1} & i_{L2}), and output voltages (V_{c2}) of positive output Luo converter are shown in figure 4.

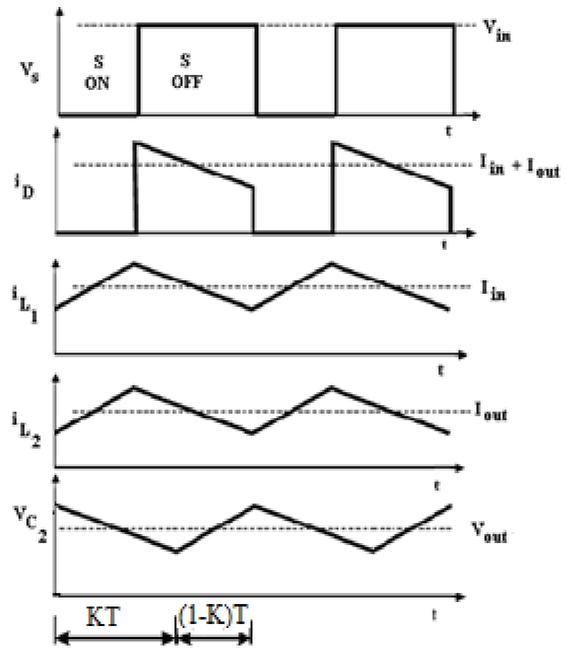

Figure 4. Theoretical waveforms of positive output Luo converter

The average DC output voltage is given by

$$V_o = \frac{K}{1-K} V_{in} \qquad \text{------- (1)}$$

The average DC input current is given by

$$I_{in} = \frac{K}{1-K} I_o \qquad \text{------- (2)}$$

The variation in inductor current ΔI_{L1} is given by

$$\Delta I_{L1} = \frac{KT}{L_1} V_{in} \qquad \text{------- (3)}$$

The variation in inductor current ΔI_{L2} is given by

$$\Delta I_{L2} = \frac{KT}{L_2} V_{in} \qquad \text{------- (4)}$$

Where, K is the duty ratio
V_{in} is the supply voltage
T is the time period of the switch.

III. CURRENT CONTROLLED POSITIVE OUTPUT LUO CONVERTER

To design the positive output Luo converter, the following circuit parameters are chosen as follows,

Supply Voltage	V_{in} = 12 V
Output Voltage	V_o = 12 V
Inductor	L_1 and L_2 = 100μH
Capacitor	C_1 and C_2= 10 μF
Load Resistance	R_0 = 10Ω
Switching frequency	F_s = 50 KHz
Load Current	I_L = (0-2) A

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The figure 5. shows the current controlled positive output Luo converter. If the reference current (I_{ref}) of range (2.5 -5) A changes, the period-1 operation of the converter enters into chaotic region through the period of doubling called period-2 operation.

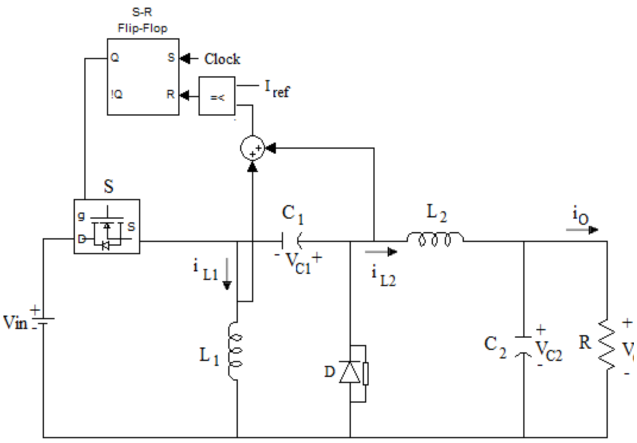

Figure 5. Circuit diagram of Current controlled positive output Luo converter

A. *Period-1 Operation*

By choosing the value of reference current as I_{ref} = 3.2A, the period-1 operation has been found. The Simulated waveforms of positive output Luo converter in period-1 operation is shown in figure 6.

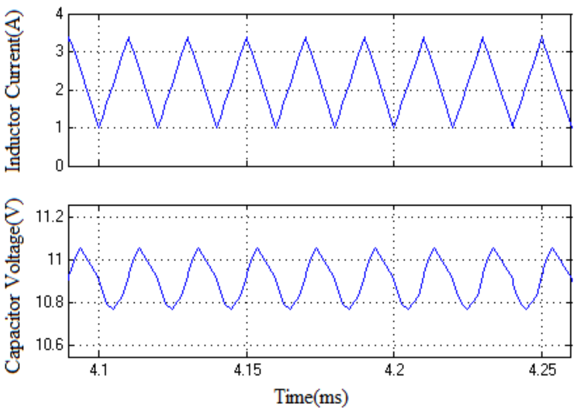

Figure 6. Simulated waveforms of positive output Luo converter in period-1 operation when I_{ref} = 3.2A

B. *Period-2 Operation*

When the reference current I_{ref} is increased to 4A, the period of doubling has found. The Simulated waveforms of positive output Luo converter in period-2 operation is shown in figure 7.

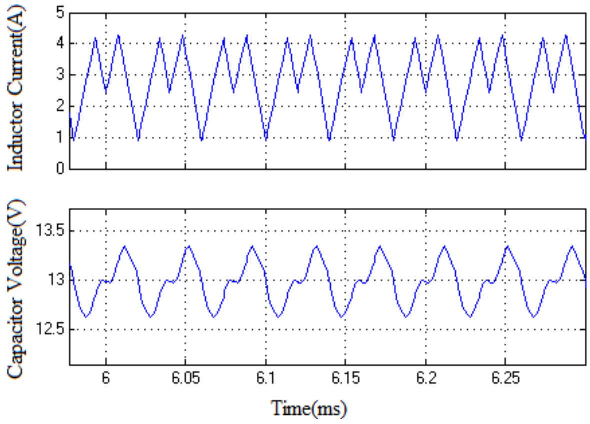

Figure 7. Simulated waveforms of positive output Luo converter in period-2 operation when I_{ref} = 4 A

C. *Chaotic Operation*

When the reference current I_{re}f is increased to 5 A, the chaotic region of the converter has been found. The Simulated waveforms of positive output Luo converter in chaotic operation is shown in figure 8.

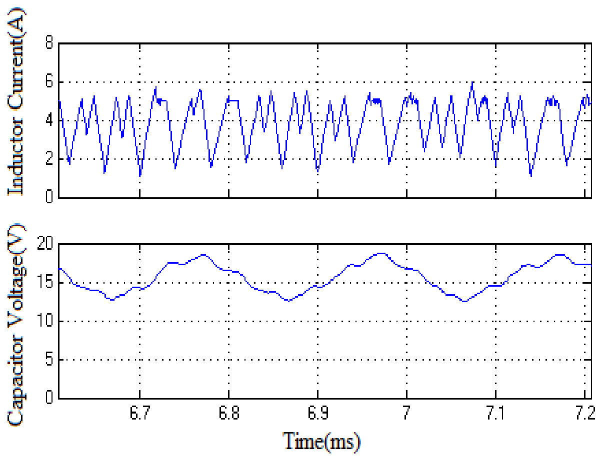

Figure 8. Simulated waveforms of positive output Luo converter in chaotic operation when I_{ref} = 5 A

IV. WEAK PERIODIC PERTURBATION METHOD

Weak Periodic Perturbation (WPP) method is used to prevent period of doubling and chaotic behavior of the positive output Luo converter when reference current I_{ref} is increased beyond certain values. In this method, reference current I_{ref} is added with the weak periodic signal to generate the modified $\tilde{I}_{ref}$ which controls the chaos in the positive output Luo converter. The current controlled positive output Luo converter with WPP is shown in figure.9

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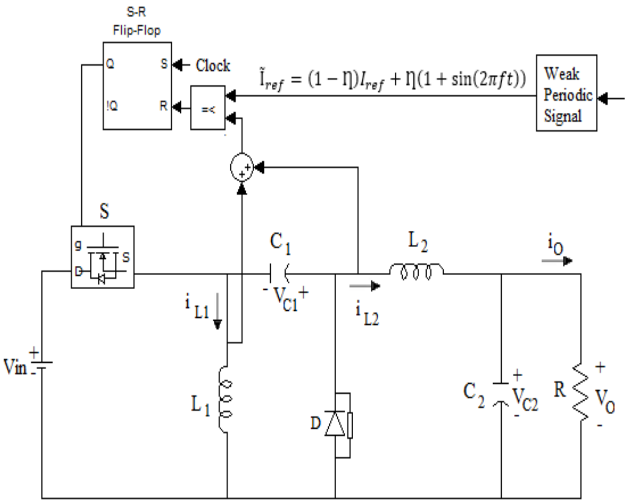

Figure 9. Current controlled Positive Output Luo converter with WPP

The modified $\tilde{I}_{ref}$ is given by,

$$\tilde{I}_{ref} = (1-\eta)I_{ref} + \eta(1+\sin(2\pi ft))$$

Where,

η is the perturbation amplitude

f is the perturbation frequency.

By using WPP, the period-2 operation of the positive output Luo converter has been shifted to period-1 operation when I_{ref} = 4 A. The Simulated waveform of positive output Luo converter when I_{ref} = 4 A, η = 0.4 and ω = 200 rad/sec is shown in figure.10.

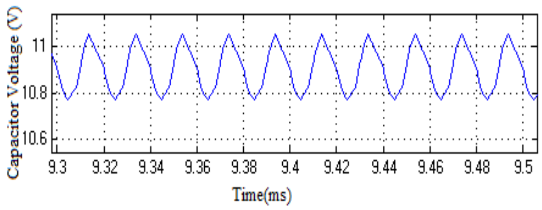

Figure 10. Simulated waveform of positive output Luo converter when I_{ref} = 4 A, η = 0.4 and ω = 200 rad/sec

By using WPP, the chaotic operation of the positive output Luo converter has been shifted to period-1 operation when I_{ref} = 5 A. The Simulated waveform of positive output Luo converter when I_{ref} = 5 A, η = 0.5 and ω = 250 rad/sec is shown in figure 11.

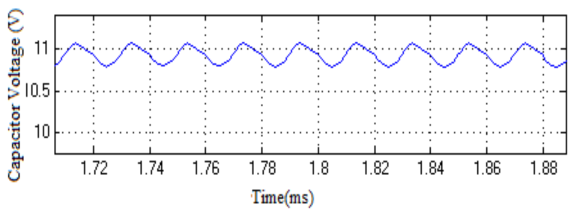

Figure 11. Simulated waveform of positive output Luo converter when I_{ref} = 5 A, η = 0.5 and ω = 250 rad/sec

V. CONCLUSION

In this paper, the weak periodic perturbation (WPP) method has been applied to control the chaos in positive output Luo converter. WPP has been implemented to stabilize an unstable operation of positive output Luo converter when the refrence current is varied. The simulations using MATLAB/ SIMULINK shows that the period of doubling and chaotic behaviour of the positive output Luo converter has been controlled by using weak periodic perturbation method.

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