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Complex Behavior Analysis and Chaos Control of Electronic Circuits

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In-depth analysis of the complex nature of the circuit, this paper discussed chaotic dynamics theory. The numerical simulation of power electronic circuits gives the complex dynamic behavior of the circuit. By theoretical analysis, to explore the root causes of the phenomenon, and through specific circuit experiment. Kinetic behavior of complex present in the circuit for establishing the corresponding chaos control method, we try to keep the original circuit structure and parameters on the basis of the system. It has excellent working stability studies which obtained the outcome. They will be a variety of power electronic circuits provide important theoretical guidance. Analyzes the general chaotic dynamical systems, in terms of the history of the development of chaos, chaos characteristics of the roads leading to chaos, chaos theory describes nonlinear systems related. Lists typical continuous dynamical systems and chaos typical discrete chaotic system dynamics, and specific analysis for studying complex phenomena of power electronic circuits provide a theoretical basis.

1. Introduction

Power electronics are strong nonlinear circuits and systems category, which is a typical non-linear direction of scientific research, with a very complex dynamics, which involves very rich nonlinear phenomena such as bifurcation, chaos, intermittent (Sarathi, 2013; Sun, 2015). This making power electronic circuits job stability has been a huge challenge (Zamani and Vaidyanathan, 2015). Through the power electronic circuits in complex behavior research can reveal the nonlinear nature of the circuit, to improve the stability of the circuit, to provide a theoretical guarantee the reliability of this type of circuit design, circuit design to provide guidance to manufacturers of power electronic circuits to meet the needs of the national economy in various fields of high stability power electronic circuits (Vasan, 2014).

With the rapid development of power electronics technology, particularly in the power electronic circuit complexity research carried out, more and more mysteries are unveiled to give a reasonable explanation, revealing the non-linear nature of power electronic circuits (Wang and Vaidyanathan, 2015), improves the performance of the circuit, making it more stable and provide a reliable guarantee for the theory of circuit design in this category, the study not only of theoretical significance also has several important practical application value research for power electronic circuits manufacturing company offers circuit design guidance, to avoid waste of resources and a decline in product quality due to improper design, saving a lot of manpower and material costs, the economic benefits are obvious, to meet the industrial, agricultural, military, civil and other fields of high-performance power electronic circuits it needs (Lang and Ding, 2013).

This article describes the chaotic dynamical systems, in terms of the history of the development of chaos, chaos characteristics of the roads leading to chaos theory describes nonlinear systems related. Study the typical continuous chaotic system dynamics and discrete dynamics typical chaotic systems, and its detailed analysis of power electronic circuits Kinetics of complex behavior provides the theoretical basis of the analysis of the switching power converter complex behavior research methods, including numerical simulation methods, research methods of theoretical analysis, experimental research methods. In voltage control mode Buck converter as an example, the study of these three methods proved switching power converter complex behavior of accuracy and consistency.

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2. Continuous chaotic system

2.1 Chaos features

Chaotic phenomenon ubiquitous in nature, chaotic strange phenomenon, but there are these different from each other in many of the same characteristics of the phenomenon (Tamba, 2016). Chaos is the product of nonlinear systems, it is not a disorder of random motion, which is a non-periodic motion, it is generally stable and in part is unstable, it looks like disorder, in fact, there is a sequence. The following mainly from the high sensitivity to the initial value, the intrinsic randomness, fractal structure with unlimited self-similarity, universality, strange attractors, continuous power spectrum, Lyapunov exponent positive aspects to analyze the chaos characteristics (Huo, 2014; Chu,2015).
The largest Lyapunov exponent values:

$$\lambda_{\max} = \lim_{m \to 0} \frac{1}{m} \sum_{i}^{m} \ln\left(\frac{d_i}{d}\right) \tag{1}$$

The maximum Lyapunov index calculation method can take two closely spaced points x (t), y (t), as shown in Figure 1.

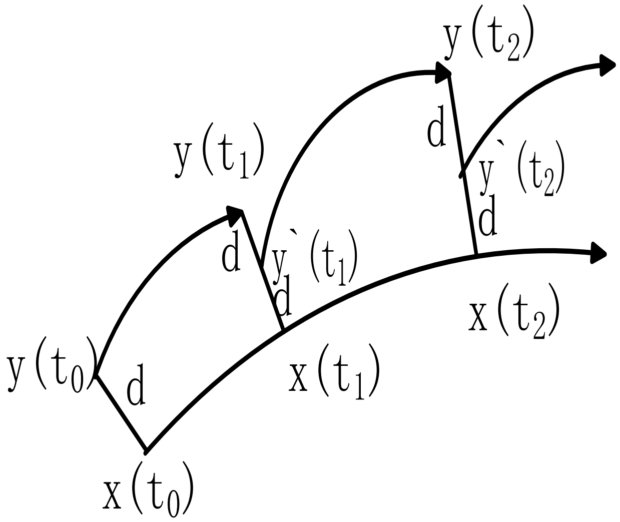


Figure 1: The maximum Lyapunov index calculation method

Their distance:

$$d = \left|y(t_0) - x(t_0)\right| \tag{2}$$

2.2 Continuous chaotic system dynamics

Typically, differential equations can be used to describe the continuous chaotic system dynamics (Vaidyanathan, 2015):

$$x(t) = f\left(x(t), k\right) \tag{3}$$

f=f $(f_1, f_2 \ldots f_n)^T$ is a continuous mapping n-dimensional space. K=$(k_1,k_2,\ldots k_n)^T \in R^m$ continuous time t corresponding to the state variables. f=f $(f_1, f_2 \ldots f_n)^T$ was the control parameters of the system.
Chua is a typical continuous chaotic systems dynamics, this study by the following typical continuous chaotic system, intrinsic dynamics of continuous chaotic systems. The circuit is composed of two capacitors, a resistor, an inductor and a nonlinear RLC circuit resistor, as shown in Figure 2.

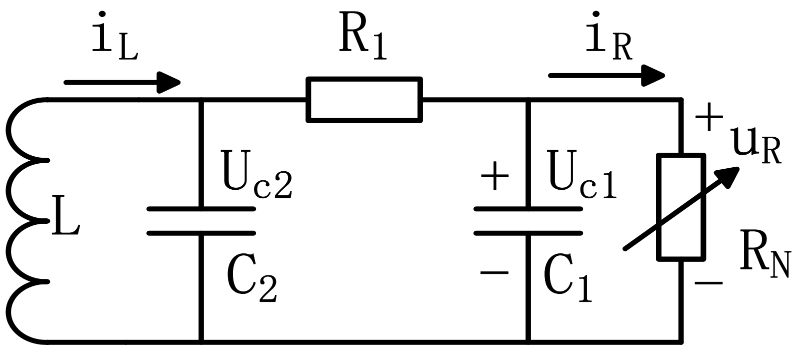


Figure 2: Circuit diagram of Chua's circuit

According to Chua's circuit diagram, using Kirchhoff's law, and the relationship between the voltage across the capacitor and the inductor current can be listed status Chua equation:

$$\begin{cases} \dfrac{du_{C1}}{dt} = \dfrac{1}{RC_1}\left(u_{C2} - u_{C1}\right) - \dfrac{1}{C_1} g\left(x\right) \\ \dfrac{du_{C2}}{dt} = \dfrac{1}{RC_2}\left(u_{C1} - u_{C2}\right) - \dfrac{i_L}{C_2} \\ \dfrac{di_L}{dt} = -\dfrac{1}{L} u_{C2} \end{cases} \tag{4}$$

Let $x=u_{c1}$, $y=u_{c2}$,$z=Ri_L$, then

$$\begin{cases} x = \dfrac{1}{RC_1}\left[y - x - Rg\left(x\right)\right] \\ y = \dfrac{1}{RC_2}\left[x - y - z\right] \\ z = -\dfrac{R}{L} y \end{cases} \tag{5}$$

g (x) function expression can be written the following expression:

$$g\left(x\right) = \begin{cases} m_1 x + m_0 - m_1; x \geq 1 \\ m_0 x; \left|x\right| < 1 \\ m_1 x - m_0 + m_1; x \leq -1 \end{cases} \tag{6}$$

3. Experiments and results

3.1 Equilibrium Point and Stability

Balance by the following equations:

$$\begin{cases} ax - yz - y + k = 0 \\ -by + xz = 0 \\ -cz + xy = 0 \end{cases} \tag{7}$$

Solve the equations, you can find:

(1) If $c<(16bk^2)/(4ab+1)^2$, the system has three balance points.

(2) If $c=(16bk^2)/(4ab+1)^2$, the system has four balance points.
(3) If $c>(16bk^2)/(4ab+1)^2$, the system has five balance points.
Through a simple analysis, we learned that five equilibrium points are unstable, and their respective characteristics shown in Table 1.

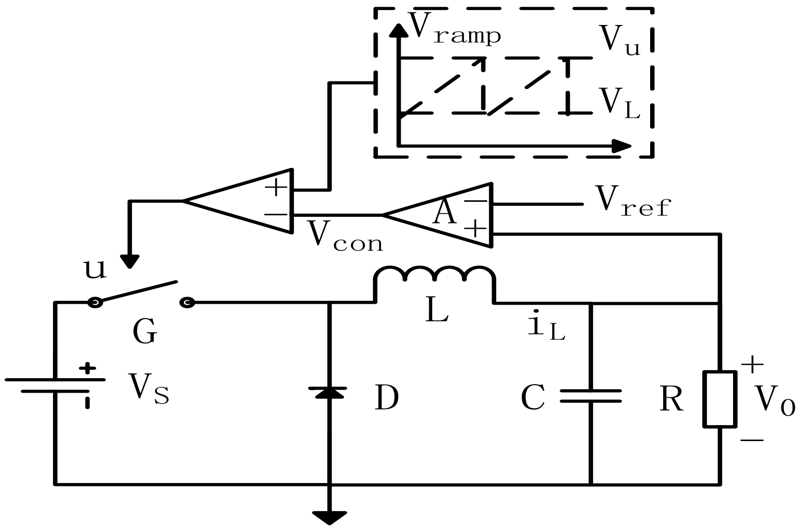
Table 1: The balance point and its latent root

Balance Points	latent root	Type
P1(0.1,0,0)	λ_1=-19.994, λ_2=-2.0006, λ_3=10,	Index-1 Unstable saddle points
P2(6.3246,4.2813,13.5388)	λ_1=-17.3374 $\lambda_{2,3}$=2.6687±8.9767i	Index-2 Unstable saddle points
P3(6.3246,-4.5976,-14.539)	λ_1=-17.4674 $\lambda_{2,3}$=2.7337±9.2741i	Index-2 Unstable saddle points
P4(-6.3246,4.6682,-14.7622)	λ_1=-17.3254 $\lambda_{2,3}$=2.6627±9.4935i	Index-2 Unstable saddle points
P5(-6.3246,-4.3520,13.7623)	λ_1=-17.1910 $\lambda_{2,3}$=2.5955±9.1981i	Index-2 Unstable saddle points

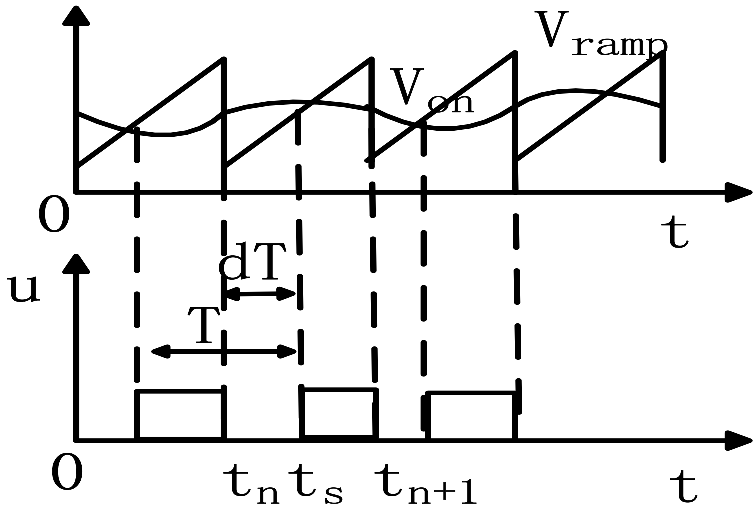
3.2 Numerical simulation

Numerical simulation method has a very important role in the dynamics of complex behavior switching power converter, which can be done using a computer, using numerical simulation software, the research object modeling, and preparation of the corresponding simulation program be implemented. Typically, it is relatively easy to implement, just know that the study works, we can give the corresponding mathematical model. It is convenient and flexible, you only need to change the value of the parameters in the program, you can change the state of motion of nonlinear dynamical systems, it can directly observe different sports results of the system.

Voltage mode control Buck converter is a very broad application of the switching power converter, its main circuit topology and voltage mode control waveforms as shown in Figure 3.



(A) Buck converter basic circuit



(b) Voltage-mode control waveforms

Figure 3: Voltage-mode control buck converter and its control waveforms

Plus noise signal, and when the perturbation intensity D = 0.004, the window range in period 3 largest Lyapunov exponent is larger than the intermittent chaos Boost converter state, as shown in Figure 4.

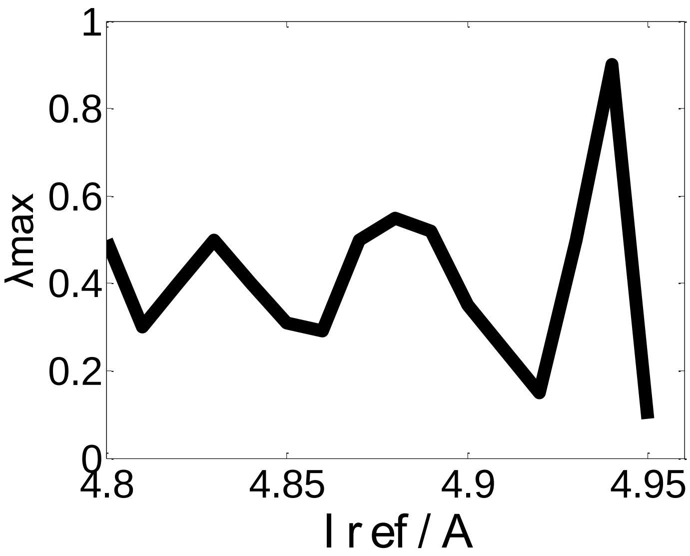


Figure 4: Lyapunov exponent is larger than the intermittent chaos Boost converter state

Fault feature extraction analog circuit fault diagnosis system is an important part, since different extraction methods from the failure characteristics of the signal in the frequency domain, so the realization of simulation and process analysis of analog circuit fault diagnosis are slightly different, here are sampling from the effective implementation of the sampling points and the wavelet transform fault feature extraction, SVM fault diagnosis were achieved on the final results of fault diagnosis further comparative analysis.

4. Conclusions

Analyzes the general chaotic dynamical systems, in terms of the history of the development of chaos, chaos characteristics of the roads leading to chaos, chaos theory describes nonlinear systems related. Lists typical continuous dynamical systems and chaos typical discrete chaotic system dynamics, and specific analysis for studying complex phenomena of power electronic circuits provide a theoretical basis. Kinetic behavior of complex present in the circuit for establishing the corresponding chaos control method, so try to keep the original circuit structure and parameters on the basis of the system has excellent working stability studies obtained the outcome will be a variety of power electronic circuits provide important theoretical guidance.

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