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PLC Implementation of a New Chaotic Chameleon System

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Abstract— This paper presents the nonlinear analysis of a new chameleon chaotic system. The model is implemented by using industrial based programmable logic controller (PLC). The system can be modeled and realized with structured text (ST) language. The different dynamical behaviors have been investigated by changing one of the system parameters and the initial conditions. The proposed system shows self-excited, hidden and coexisting attractors.

1. Introduction

Recently, there have been many works in designing and realizing of chaotic systems. It has been found that chaos has a theoretical and practical importance in many fields such as biology [1, 2], engineering [3], medicine [4], physics, encryption, image processing, navigation systems, secure civil and military communications [5].

Circuits design and realization of various complex systems have been advanced topics of the real applications of various technologies based on chaos [6]. PLC is a programmable device with special design for industrial applications and digital computing. It gives a robust and relabel system and uses one type of memory which can program it to store instructions and to form functions such as counting, sequencing, timing, conditional and arithmetic instructions for control many kinds of processes and machines by digital or analog input and output. In addition to the above properties, PLC has another advantages such as: good versatility, the installation is flexible, the ability of anti-interference [7]. This paper, introduces an experimental implementation of the chameleon chaotic system named as such for the reason that the system shows both hidden and self-excited oscillations depending system's parameter values. The different dynamics have been investigated numerically. The second aim of this paper is to implement the model using industrial PLC. XEC-DN32H device from LS XGB series, is used. The programmable hardware allows the experimental characterization of the system dynamics with reconfigurable and rapid experimental setup. The reset of the paper is organized as follows: Section 2 introduces the dynamical properties of the suggested new chaotic system. Section 3 discusses the PLC Implementation of the suggested chameleon chaotic system. A brief conclusion is given in Section 4.

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2. Dynamic Properties of the New Chaotic System

This section introduces the new chaotic chameleon system with hidden and self-excited attractors. Moreover, the model shows coexisting attractors and hysteresis nature. The suggested chaotic system's dimensionless state equations are given as follows:

$$\begin{cases} \dot{x} = y \\ \dot{y} = a(x + yz), \\ \dot{z} = x^2 + y^2 + bz(z - cx) - d \end{cases} \tag{1}$$

where a, b, c and d are system's parameters. The system (1) behaves as a self-excited attractor when $b \neq 0$ having unstable equilibrium points defined as $[0, 0, \pm\sqrt{\frac{d}{b}}]$ and when $b = 0$ the system doesn't have defined equilibrium points and hence shows hidden chaotic oscillations. To find the dynamical behavior of the proposed chaotic system, the modern nonlinear analysis tools such as the bicoherence, power spectral density (PSD), Poincaré map, bifurcation diagram, Lyapunov exponents were used. The self-excited attractor of the chameleon chaotic system (1) at $b \neq 0$ is shown in Fig. 1 a and b. Where system parameter are selected as $a = 6, c = 0.1, d = 0.605$. The system dynamics are evolved on a torus. On the other hand, Fig. 1 c and d where $b = 0$ show the dynamic of the hidden attractor.

The bicoherence of the system which is related to the nonlinearity strength is given in Fig. 2. The power spectral density plot given in Fig. 2, indicates the broadband nature of the suggested chaotic system. Moreover, the Poincaré map of the system in the $x = 0$ plan is depicted in Fig. 3.

The bifurcation plots of the system for the control parameter d, is depicted in Fig. 4. It shows the bifurcation of the system with forward continuation blue where the parameter d is increased from 0.57 to 0.65 with the initial condition for the initial iteration taken as $[0.5, 0.5, 0.5]$ and is reinitialized to the end values of the state variables. The green plot shows the backward continuation with the