Chaotic motions and fractal basin boundaries of attractors in state feedback control of PMSM

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Abstract

This paper investigates the period doubling bifurcation and the chaotic response of the state feedback control of permanent magnet synchronous motor (PMSM). In this system besides of chaotic attractors, multiple regular attractors may co-exist for some values of system parameters, and it is important to study the global behavior of the system using the basin boundaries of the attractors. Here multiple scales method is used to distinguish the regions of stable and unstable attractors. Early studies show that there are unstable regions for the PMSM control. Thus, in this paper using bifurcation diagrams and phase plane, it is shown that in some cases the response of machine becomes quasi periodic or chaotic for some deviations from external and internal perturbation parameters. Also it will be shown that the response is sensitive to the value of state feedback controller parameters, which may result in chaotic response. Results show that the jumping phenomena may occur when multiple regular attractors exist. Using basin boundaries of attractors it is also shown that in some regions these boundaries are fractal.

Key words: Attraction Basin, Feedback control, PMSM, Bifurcation, Chaos..

1 Introduction

In many nonlinear dissipative dynamical systems, after driving the equations of motion, one usually tries to locate all possible equilibrium states and periodic solutions of the system and specify the stability of these solutions. Also for multiple solutions, evolution of the solution due to variations in system parameters or initial conditions would be important. In recent years strange attractors have been found in many nonlinear dynamical systems, so one must examine the probability of chaos when the system is nonlinear. In many applications chaotic response is undesirable, because even small perturbations may cause trajectories to diverge exponentially [1][2][3][4].

DC motors, step motors and permanent magnet synchronous motor (PMSM) have a chaotique behavior in many situations when different system parameters varied in some area. Li and Zhang et al focus his work to detect the chaotique behavior in PMSM which performs various and complex dynamic behaviors, [5]. Many important works are executed to control chaos in PMSM. The method which existed can be worked theoretically because of much reason such that the transformation and the simplification of the mathematical model of the system and the reducing of parameter number, [5]. Practically, the controlling of the permanent magnet synchronous motors needs some correctors parameters such that an integrator corrector. So, Its necessary to add the equation of this corrector in order to approach to the real model of system.

2 State Feedback controller

Thus, the system non-linearity is exactly cancelled. This linearization is valid for all operating points.

$$\begin{cases} \frac{dx_1}{dt} = \beta_1 x_1 + n_p x_2 x_3 + \beta_2 x_2 + \beta_3 x_3 + \frac{u_{dref}}{L} \\ \frac{dx_2}{dt} = \beta_1 x_2 - n_p x_1 x_3 + \beta_4 x_1 + \beta_5 x_3 + \frac{u_{dref}}{L} \\ \frac{dx_3}{dt} = c_1 x_2 + c_2 x_3 - \frac{1}{J} T_L \end{cases} \quad (1)$$

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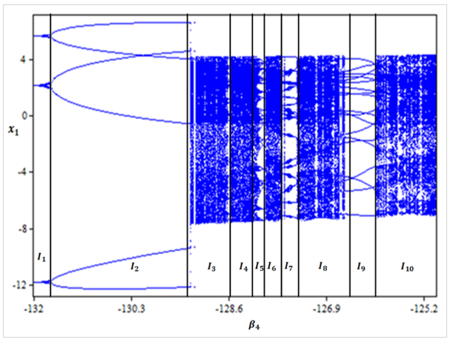
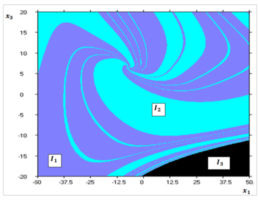
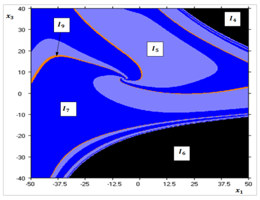


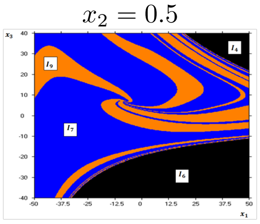
Fig. 1. Diagram bifurcation $\beta_4 - x_1$ for initial condition $x_i = (0.1, 0.1, 0.1)$



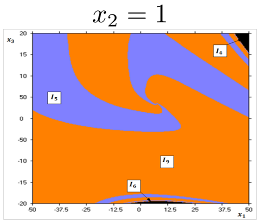
$x_2 = 0.5$



$x_2 = 1$



$x_2 = 0$



$x_2 = -1$

Fig. 2. Coexistence of attractors in attraction basin $x_1 - x_3$

with $\beta_1 = -\frac{R_s + k_{1d}}{L}$, $\beta_2 = \frac{k_{2d}}{L}$, $\beta_3 = \frac{k_{3d}}{L}$,$\beta_4 = \frac{k_{1q}}{L}$, $\beta_5 = -\frac{n_p \phi_f + k_{3q}}{L}$,$c_1 = \frac{n_p m \phi_f}{2J}$, $c_2 = -\frac{f}{J}$ and $k_{1d} = k_{2q}$

3 Dynamics for Regions in the attraction basin

We take each region in Figure 1 in turn and discuss the likely dynamics and their practical implications. Where applicable we include bassin attractions plots of typical trajectories, see figure2.

4 Conclusion

This study details the quasi periodic response of PMSM state feedback control. Although earlier studies show that the response in some regions become unstable because of the existence of period doubling bifurcation, we have shown that there are also the possibility of quasi-periodic and chaotic solutions. Our investigations illustrated that deviation from the internal or external perturbations of parameters may result in quasi-periodic or chaotic states.

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