Stabilization of Period Doubling Bifurcations and Chaos of Field Oriented Control of Permanent Magnet Synchronous Motor

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Abstract

The stabilization of period doubling bifurcations and route to chaos for field oriented control of permanent magnet synchronous motor (PMSM) is investigated. It is shown that generically such bifurcations theory can be stabilized using field oriented control, even if the linearized system is uncontrollable at criticality. In the course of the analysis, expressions are derived for bifurcation stability coefficients of general n- dimensional systems undergoing period doubling bifurcation and route to chaos. A connection is determined between control of the amplitude of a period doubled orbit and the elimination of subharmonic frequencies. For illustration, the results are verified by numerical simulation.

Key words: Period Doubling, PMSM, Bifurcation, Control, Chaos.

1 Introduction

Nonlinear dynamical systems are, in general, prone to exhibit an exordinarily rich spectrum of dynamical behaviour [1]. Recent studies have shown that the influence of different kinds of additional perturbations and external forcings [2] on these systems is considerable and they can alter the dynamical behaviour dramatically. For example, the addition of a periodic forcing to a single-degree-of-freedom nonlinear oscillator system can introduce various dynamical phenomena such as chaos, phase-locking, mode-locking, period-doubling, quasi-periodicity, intermittency, and crises. Also, the addition of constant bias, noise, parametric excitations, etc., can suppress the chaotic behaviour by converting the system dynamics to any desired periodic attractor through period-doubling reversals or other complicated bifurcations [1] [3]. on the other point, the investigation of bifurcations in electric motors is a field of active research due to its direct applications in many areas, such as, industrial machinery, electrical locomotives and electrical submersibles thruster drives,[7]. The appearing of bifurcations phenomena in machine drives allows us to study the real stability of system. Bifurcation control has been designed for stationary, Hopf, period-doubling bifurcations and chaotic motions, etc. Many research works on chaos control and synchronization of two chaotic systems have born great fruits. However, there are fewer investigations on bifurcation control relative to chaos control [3]. For Hopf bifurcation control, Abed and Fu designed a static state feedback controller by for discrete maps. This phenomena of loss of stability is associated with a hopf bifurcation where a periodic oscillation emerges from a stable equilibrium point EP and another small perturbation on the machine parameters provokes the onset of growing oscillation. Then, the dynamics behavior of permanent magnet synchronous motor is studied by means of modern nonlinear theories such as bifurcation and chaos, [5], [6], [7].

The paper is organized as follows: the first section concern to explain the method which used to explain the nonlinear dynamic of PMSM driver. In section2, a dynamic model of system will be detailed where a numerically conditions are analyzed for the appearing of the period doubling bifurcation. Finally, a subharmonic Oscillations and routes to chaos phenomena will be expressed in order to analysis the non linear dynamic behavior of

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system.

2 Dynamic description of system

The stator voltage equations in the synchronous rotating frame is shown as follows:

$$\begin{cases} f_1(x) = L_d \frac{di_d}{dt} = -R_s i_d + pL_q i_q \Omega + v_d \\ f_2(x) = L_q \frac{di_q}{dt} = -R_s i_q - pL_d i_d \Omega - p\phi_f \Omega + v_q \end{cases} \quad (1)$$

The torque balance equation of the given system is

$$f_3(x) = J\frac{d\Omega}{dt} = \frac{n_p.m\phi_f}{2} i_q + \frac{n_p.m(L_d - L_q)}{2} i_d i_q - f\Omega - T_L (2)$$

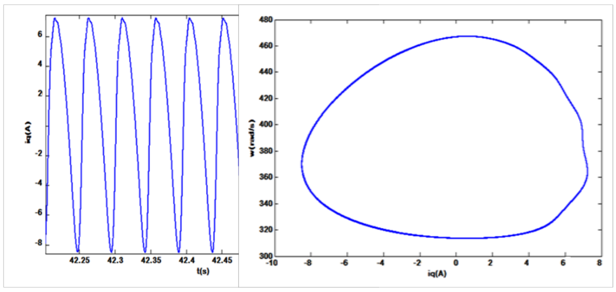
The integrals regulators will be expressed by the following three expressions:

$$f_4(x) = \frac{dI_{id}}{dt} = k_i(i_{idref} - i_d) \quad (3)$$

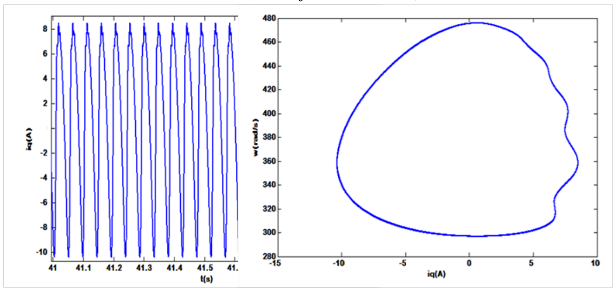
$$f_5(x) = \frac{dI_{iq}}{dt} = k_i(k_{pw}(\omega_{ref} - \omega) + I_w - i_q) \quad (4)$$

$$f_6(x) = \frac{dI_w}{dt} = k_{iw}(\omega_{ref} - \omega) \quad (5)$$

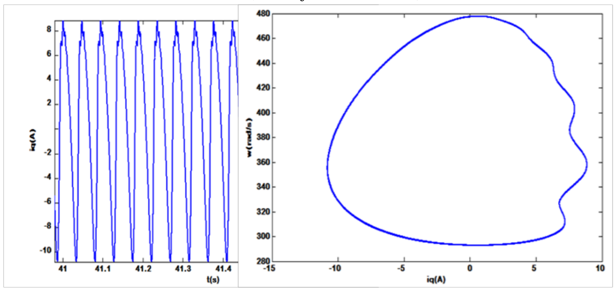
For a chaotic PMSM driver, it is interested in identifying how to route to chaos with respect to the variation in external system parameters. As a parameter is varied, a bifurcation is an abrupt change in the periodic behavior of the PMSM,see figure1



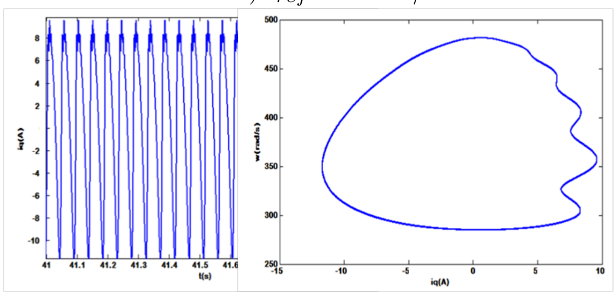
a)$\omega_{ref} = 50rad/s$



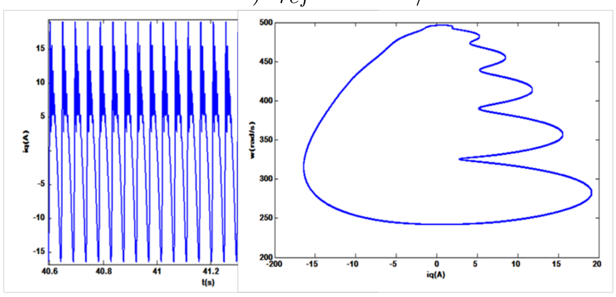
b)$\omega_{ref} = 60rad/s$



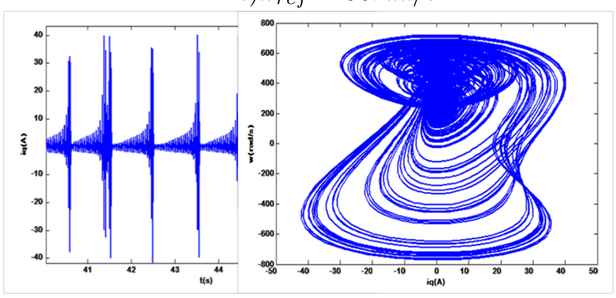
c)$\omega_{ref} = 70rad/s$



d)$\omega_{ref} = 80rad/s$



e)$\omega_{ref} = 90rad/s$



f)$\omega_{ref} = 110rad/s$

Fig. 1. Increasing of subharmonic in temporal domain and phase portrait of Periodic behavior of system

3 Conclusion

In this paper, period doubling bifurcation diagrams that leads to chaos in the field oriented control of PMSM are observed by varying the speed proportional parameter. To ensure stable operation an adaptive controller based on field oriented control principle is designed. Simulation results show that the proposed controller is very effective and robust with respect to both the parameters variation in system and external disturbance.

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