Analyzing Complex dynamics and chaos in electrical energy conversion systems

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Abstract — This talk addresses a review of tools and methods to analyze experimental or computed chaotic data series in the context of electrical engineering. As an example, a prototype of linear switched reluctance motor which encounters chaotic behaviors under some specific feeding conditions is analyzed. At first, the nonlinear phenomena, as bifurcations and chaos, are observed by simulating a five dimensional simplified model. The main approach is to develop a methodology for evaluating the fractal dimension and validate it on simulated data before applying it to experimental data produced by the instrumented test bench. Note that very few experimental chaos in electrical machine have been reported in literature [1]. An other example concerns the analysis of bifurcation diagrams of a power electronics DC/AC converter under a current mode control.

SUMMARY

This talk deals with a review of tools and methods to analyze experimental or computed chaotic data series in the context of electrical engineering and more precisely for the energy conversion.

The first case study addresses a prototype of a linear switched reluctance motor. Many manufacturing processes requiring high-precision linear position control, as pick-and-place machines, involve these kinds of machine. This motor present a highly nonlinear dynamic because the discrete nature of torque production mechanism. The hard nonlinearity is mainly due to the strong dependence between translator position and air-gap permeance.

From this kind of machine, some works about step motors [2]-[5] have detected many nonlinear phenomena. Because of this very complex dynamics nature, these motors are susceptible to exhibit different types of behaviors even in open loop operation. In addition to usual periodic orbits, quasi-periodic and chaotic behaviors have been reported.

It has been shown [6], that a simplified dimensionless harmonic model, stemmed from a precise flux tubes model, gives results very similar to the exact model, especially in chaotic modes, because bifurcations and chaos arise from the main non linearities of the motor and do not result from some modeling details. This model has been successfully used to evaluate fractal properties of chaotic motions of the motor by the mean of intensive computations [7].

The talk presented also some experimental result showing, for example, how to predict the experimental forecast horizon using a carefully computed Lyapunov spectrum.

The second case study concerns a DC/AC static converter [9]. The inverter is connected to a DC voltage source and it is feeding a passive resistive and inductive load. It’s observed that under a current mode control [10], the inverter exhibits many nonlinear phenomena, some of them being highly dependent on the technology of the PWM modulator.

It wills be shown that some special bifurcation diagrams can add insightful information on intimate details of original bifurcation diagram [11]. The utility of these tools will be demonstrated especially, for the detection of synchronisation modes of the inverter inside the chaotic zone.

BIBLIOGRAPHY


