Control of chaos in a simple power system model

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The studies of bifurcations in power system models have increased considerably in the last two decades. This followed a trend of study in other fields of engineering. Simple models of a power system may consist of several differential equations. The nominal operating condition of such models can be an equilibrium point or a limit cycle. The electric power system normally functions at a stable operating point. A bifurcation is a change in the number of candidate operating conditions of a nonlinear system as a parameter is quasistatically varied. There are different types of bifurcations. Local bifurcations can be detected from linearizations of the nonlinear set of equations at a given operating point. Among the possible local bifurcations only two are generic, i.e., preserved under small perturbations. These are the saddle-node and Andronov-Hopf bifurcations. The limit sets emerging from these bifurcations often undergo further bifurcations. The first bifurcation, which occurs along the nominal solution branch, is termed a primary bifurcation. A bifurcation from the solution emanating from the primary bifurcation is termed a secondary bifurcation. Successive bifurcations can become rather complex, and can lead to chaotic (or turbulent) behavior. Chaos is an irregular, seemingly random dynamic behavior displaying extreme sensitivity to initial conditions. Nearly initial conditions result, at least initially, in trajectories that diverge exponentially fast.

Complex behavior in power system models has been reported extensively. The models used varied in complexity from a few differential equations up to two dozen equations. Voltage collapse which is relatively a recent phenomenon, has been recorded in many large power system around the world. There is a general consensus that bifurcations in underlying mathematical models of a power system are closely linked with voltage collapse. This fact makes the study of such bifurcations and their control important. Control of parametrized families of systems may be feedforward or feedback. Linear dynamic feedback control has been in use in power systems for many decades. It can stabilize an unstable operating point. Nonlinear feedback control can be used to alter the behavior of the system. The bifurcations and their nature may be altered by this nonlinear feedback control.

In this presentation we will consider two systems. A fourth order model of a three node system with a load that includes an induction motor is represented by the first four differential equations. The notations are those used in [1,2]. We will call this system (1). If a field winding and a fast exciter are added to the system two additional equations (5) and
(6) are added and the resulting system with six equations we call system (2).

\[
\begin{align*}
\dot{\delta} &= \omega_B S_m \quad (1) \\
\dot{S}_m &= \frac{1}{2H}(-P_g + P_m - dS_m) \quad (2) \\
\dot{\delta}_L &= \frac{1}{q_1}(Q - Q_{ld} - Q_0 - q_2 V_L - q_3 V_L^2) \quad (3) \\
\dot{V}_L &= \frac{1}{p_2}(P - P_{ld} - P_0 - p_1 \dot{\delta}_L - p_3 V_L) \quad (4) \\
\dot{E}_q' &= \frac{1}{T_{do}'}(E_{fd} - (x_d - x_q')i_d - E_q') \quad (5) \\
\dot{E}_{fd}' &= \frac{1}{T_A'}(K_A (V_{ref} - V_i) - E_{fd}) \quad (6)
\end{align*}
\]

The dynamics of system (1) were studied [1-5]. We applied nonlinear control by employing a speed signal, which altered the bifurcations appreciably [3-5]. We used reactive power as a bifurcation parameter. System (2) exhibits more routes to chaos as reported in [2]. Currently work is in progress to apply control to system (2). following [1,2] we will use mechanical power input as a bifurcation parameter. In system (2) reference [2] reports three routes to chaos: a period-doubling cascade to chaos, intermittancy and a torus breakdown to a chaotic behavior. System (2) permits different types of control.

1 References


