Non-singular Terminal Sliding Mode Chaos Control and Multistability Behaviours in 3-Bus Power System Model

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Abstract. In this paper, annihilation of chaos behaviour and presence of multistability behaviour in a 3-bus power system model is discussed. The 3-bus power system modeling is achieved by using generator, constant load models and by obtaining the equivalent circuit of 3-bus system. The existence of chaos and multistability phenomena is analysed using different tools such as phase plane behavior, time series plot, Poincare map, bifurcation diagram, Lyapunov exponent. Unlike the design of discontinuous terminal sliding mode control (TSMC) has the possibility of unbounded nature of control inputs results in singular dynamics of the 3-bus power system which induces singularity and unwanted chattering problems. A non-singular terminal sliding mode control (NS-TSMC) is designed to control the chaotic behaviour in the 3-bus power system model. The NS-TSMC method is designed by selecting a non-singular terminal sliding surface, which helps in finite time convergence and stability of the dynamic states of 3-bus power system. The proposed NS-TSMC control method avoids singularity and reduces the chattering problem. Simulations are done in MATLAB environment to verify the analytical approach.

Introduction

Chaos phenomena in the power system produces electromechanical oscillation which may destroy the stability or reliability of system or be a reason for voltage collapse [1, 2]. This unwanted disturbance is inevitable in the power system and plays a very important prologue in the stability and reliability of large power system [3]. Recent decades a lot of research have been reported to study the chaos behaviour in various fields of engineering including power systems [4-6]. Chaos behaviour is undesirable in the power system or network due to nonlinear characteristics and research on chaos behaviour and its control in power systems is a dire need and important nowadays.

Literature reveals that the reported discontinuous SMC in [7-9] has major disadvantages such as high frequency and amplitude of oscillation in control input and an unwanted chattering in sliding surface which are undesirable in industrial application [9]. Here, NS-TSMC is designed to avoid singularity, chattering problems and to control the chaos behaviour in the 3-bus power system (Fig. 1, in middle), where the reaching control law approach is used to get chattering free response where a continuous saturation function is present in the derived control input. This continuous switching control input contains saturation function related with the state trajectory approach angle θ. This angle measures the orientation of the state trajectory with respect to the sliding surface. In the designed NS-TSMC, the convergence time can be reduced by adjusting sliding surface parameter. NS-TSMC assists us to converge all state variables without spending a large control effort within finite time duration and shown in Fig. 1 (in right).

Further, in this research, when a 3-bus power system is subjected to disturbances such as voltage dips, voltage surges, frequency variation, rapid voltage change or imbalance can change machine angle, load angle, load voltage and load reactive power demand. This change is considered by changing the initial conditions and this may force the 3-bus power system to move from one stable state to multistable or even unstable state. As the sinusoidal and co-sinusoidal nonlinearities are present in the dynamic equations of 3-bus power system model, it has multistability behaviour alongside chaos behaviour as shown in Fig. 1 (in left).

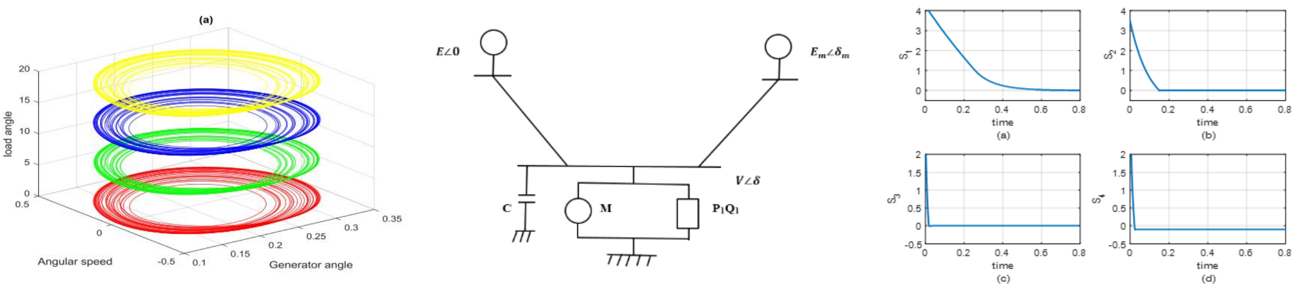

Figure 1: The 3-bus power system model (in middle), chaos control using NS-TSMC (in left) and existence of multistability behaviour (in right).

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