Limit cycle oscillation induced by backlash in hydropower regulation process

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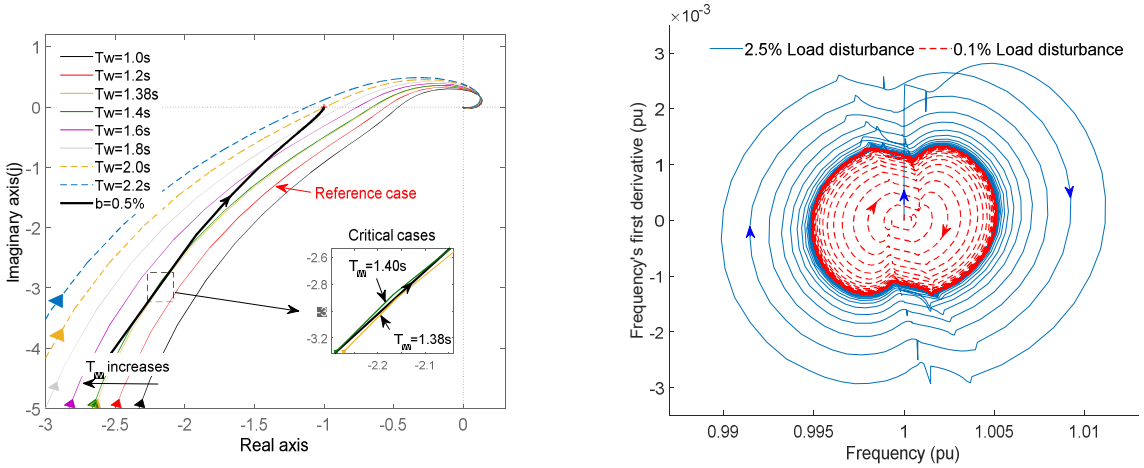
Abstract. Dynamic regulation stability of hydropower units is crucial for power systems, especially under the consideration of potential instability caused by nonlinearities. With the increase of service life and aging of actuators, the influence of the backlash in hydro-turbine governing system becomes more important. Hence, in this paper, the dynamic response and limit cycle oscillation induced by backlash of hydropower generating system (HGS) is investigated. A nonlinear mathematical model for HGS is presented; the Nyquist stability criterion is applied, and time-domain simulation is conducted for validation by adopting MATLAB. The results present the characteristic of the limit cycle oscillation, and its influence on the active power and rotational speed of HGS. The matching law between the backlash and the representative parameters in HGS is studied to obtain better regulation quality. This work could contribute to the understanding and application of nonlinear dynamics in hydropower field.

Introduction

Hydropower, presently as the largest renewable energy source, also shoulders the important regulation duty for renewable power system with intermittent energy sources. The dynamic stability in hydropower regulation process is of great significance for power systems; specifically, a hydropower generating system (HGS) is a nonlinear complex system with hydro-mechanical-electrical coupling, and the potential instability caused by nonlinearities is worth investigating. With the increase of service life and the aging of actuators of hydropower units, the influence and importance of the backlash in hydro-turbine governing system is becoming more obvious. A lot of meaningful research have been carried out on nonlinear stability and characteristics of HGS; however, specific study on the backlash in HGS is rarely conducted in previous works, and the characteristic and impact of limit cycle oscillation induced by backlash for hydropower regulation process need to be clarified. Hence, in this paper, the dynamic response and limit cycle oscillation induced by backlash of HGS is studied.

Result and contribution



(a) (b)

Figure 1: Representative figures of the results under different operation conditions: (a) Nyquist curves; (b) Phase diagram for oscillations

In this work, the characteristic of the limit cycle oscillation, and its influence on the oscillation of active power and rotational speed (power grid frequency) of HGS, are presented. The influence mechanism of important hydraulic-mechanical factors on the stability of the nonlinear system with backlash is discussed. Representative figures of the results under different regulation conditions are shown in Figure 1. The matching law between the backlash characteristics and the representative parameters in HGS is studied to obtain better regulation quality of hydropower units. This work could contribute to the understanding and application of nonlinear dynamics in hydropower field.