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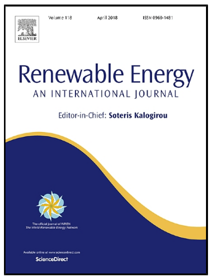

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Modeling and dynamic response control for primary frequency regulation of hydro-turbine governing system with surge tank

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Abstract: This paper aims to study the modeling and dynamic response control for primary frequency regulation of hydro-turbine governing system with surge tank. Firstly, the index of dynamic response control for primary frequency regulation is selected and illustrated. Then, the sine wave assumption of water level oscillation in surge tank is proposed, and a novel simplified model for hydro-turbine governing system is obtained. Using the simplified model, the analytical expression for dynamic response of power output is derived. Finally, the concept for the domain of primary frequency regulation is proposed. The effects of influence factors on response performance of primary frequency regulation are analyzed. The results indicate that water level oscillation in surge tank can be assumed as a sine wave. The assumed sine oscillation describes the characteristics of the unsteady flow in headrace tunnel and surge tank. The analytical solution for dynamic response of power output obtained from the sine wave assumption is reasonable and has good accuracy. The dynamic response of power output is superposed by four independent subwaves. The response performance of primary frequency regulation can be quantitatively evaluated by domain of primary frequency regulation. The larger the domain of primary frequency regulation, the better the response performance.

Keywords: hydro-turbine governing system; surge tank; primary frequency regulation; mathematical modeling; dynamic response control.

1. Introduction

Primary frequency regulation is one of the main control actions of load frequency control taken against frequency deviations in the grid as a result of unbalances between demand and supply [1]. Variation in load frequency is an index for normal operation of power systems. To ensure good grid power quality when the grid load changes, the grid frequency should be controlled in the allowable variation range of rated frequency [2–4]. All the units contributing to primary frequency regulation give active power support automatically by increasing or decreasing their active power output depending on the signal of the frequency deviation [5,6]. For the hydropower station, primary frequency regulation is actualized by the hydro-turbine governing system, and the core component is the governor [7,8].

For the primary frequency regulation of hydro-turbine governing system, researches and applications are considered from three aspects: model, characteristics and control. Representative achievements are stated as follows:

(1) For the model, Zhang et al. [9] established the control system model at the opening closed-loop control mode and power closed-loop control mode for the hydro generator units, respectively. Yang et al. [10] built a model for primary frequency control under guide vane opening feedback control mode for hydroelectric generating unit, and the model was validated with data from full scale measurements.

(2) For the characteristics, Wei et al. [11] carried out the analysis and simulation on the primary frequency regulation and isolated grid operation characteristics of hydraulic turbine regulating systems, and revealed the impacts of the regulated objects and the parameters of hydraulic turbine control systems on the primary frequency operation and the dynamic characteristics of an isolated grid. Zhang et al. [12] studied the stability of primary frequency regulating system of hydroelectric units and analyzed the effect of the superior excitation control on enhancing primary frequency regulating stability of the grid. Cebeci et al. [13] discussed the effects of hydro power plants' governor settings on the stability of power system frequency.

(3) For the control, Zhao et al. [14] presented a systematic method to design ubiquitous continuous fast-acting distributed load control for primary frequency regulation in power networks by formulating an optimal load control problem. Pourmousavi et al. [15] presented a comprehensive central demand response algorithm for frequency regulation, while minimizing the amount of manipulated load, in a smart microgrid. Bao et al. [16] designed a hybrid hierarchical demand response control scheme to support frequency control and discussed the parameters settings in detail. Morel et al. [17] presented a robust control approach to enhance the participation of variable speed turbines in the primary frequency regulation during network disturbances to improve the closed-loop performance.

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