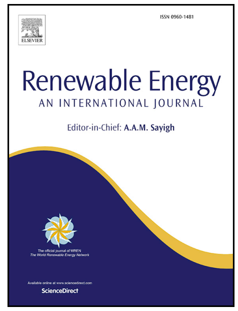

Surge wave characteristics for hydropower station with upstream series double surge tanks in load rejection transient

Wencheng Guo, Jiandong Yang, Yi Teng

PII: S0960-1481(17)30184-2

DOI: 10.1016/j.renene.2017.03.005

Reference: RENE 8598

To appear in: *Renewable Energy*

Received Date: 11 September 2016

Revised Date: 23 January 2017

Accepted Date: 1 March 2017

Surge wave characteristics for hydropower station with upstream series double surge tanks in load rejection transient

Wencheng Guo [a,b *], Jiandong Yang [a], Yi Teng [a,c]

[a] *State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan, 430072, China*
[b] *Maha Fluid Power Research Center, Department of Agricultural and Biological Engineering, Purdue University, West Lafayette, 47907, USA*
[c] *Sichuan Water Resources and Hydroelectric Investigation & Design Institute, Chengdu, 610072, China*

Abstract: In order to reveal the surge wave characteristics and provide design guidances for the hydropower station with upstream series double surge tanks in load rejection transient, this paper studies the water level oscillations in the surge tanks. Firstly, the mathematical model that describes the unsteady flow for pipelines system is established. Then, for undamped upstream series double surge tanks system, the water level oscillations in two surge tanks are studied by deriving the analytical formulas with a novel method and analyzing the oscillation characteristics and superposition mechanism of water levels. The effects of damping on water level oscillations are analyzed. Finally, the application guidances of the results for the design of surge tanks and headrace tunnels are proposed. It is demonstrated that: Under the assumption of step discharge change in penstock, the proposed method for the derivation of analytical formulas for water level oscillations is effective, and the obtained analytical formulas are reasonable and have good accuracy. For the water level oscillations in two surge tanks, there are two kinds of frequency for the subwaves (i.e. subwave 1 and subwave 2). Subwave 1 and subwave 2 are the fundamental wave and the harmonic wave, respectively. The amplitude of subwave 1 determines the basic range of the water level oscillation. The damping mainly affects the attenuation of the water level oscillations. The analysis results for surge wave characteristics can be applied to the design of real projects.

Keywords: hydropower station; upstream series double surge tanks; water level oscillation; wave superposition; damping; load rejection.

1. Introduction

Hydropower station with super-long distance headrace tunnel is one of the important development methods for hydroelectric energy. For this kind of development method, the core feature is that the hydropower station obtains high working head by using a super-long distance headrace tunnel, which is usually longer than 5 kilometers [1]. Nowadays, this kind of hydropower station has been widely adopted.

The flow inertia of the super-long distance headrace tunnel is extremely large. In order to guarantee the security and stability of hydro-turbine unit operations, pressure reduction facilities must be set on the headrace tunnel. The most commonly used facility of pressure reduction for hydropower stations is the surge tank [2,3]. The setting of surge tank can effectively shorten the length of penstock and then decrease the water hammer pressures in load rejection transient process [4–7]. Generally, only one surge tank is set on the headrace tunnel [2,3,7]. However, for hydropower station with super-long distance headrace tunnel, the extremely large flow inertia of the tunnel always leads to a huge cross-sectional area of surge tank [8,9]. The surge tank with huge cross-sectional area brings great difficulties and challenges for the design, construction and operation of hydropower station. The difficulties and challenges can be expounded from the following three aspects: (1) The layouts of pipelines system become extremely difficult; (2) The surrounding rock stability of surge tank and underground powerhouse becomes extremely dangerous; (3) The flow pattern of the unsteady flow in the surge tank becomes extremely complicated.

In order to overcome the above problems brought by the setting of upstream single surge tank (USST) on the super-long distance headrace tunnel, the design scheme of upstream series double surge tanks (USDST) has been put forward. Two surge tanks are set in series on the headrace tunnel. As a result, the cross-sectional area for each surge tank can be reduced greatly, meanwhile, the water hammer pressures in load rejection transient process can still be decreased effectively. At present, hydropower station with USDST has attracted widespread concerns. However, the researches on the working principles and design theories for USDST are still at the initial stage. Very limited achievements mainly focus on the stability analysis of hydro-turbine governing system. Representative achievements are stated as follows: Li et al [10] gave an application of a hydropower station with USDST solved by characteristics method of transient flow and discussed the influence of pipeline factors on the stability of small water fluctuation in surge tanks. Teng et al [11] developed a complete mathematical model including diversion pipeline, surge tanks, hydraulic turbine, speed governor and generators, and then derived the comprehensive transfer function and linear homogeneous differential equation. The effects of the fluid inertia of water diversion system on stability were analyzed using stability domains. Based on the Thoma assumption, Chen

* Corresponding author. Tel.: +86 027 68772274; fax: +86 027 68772310.
E-mail address: wench@whu.edu.cn (W. Guo).