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EXPERIMENTAL VALIDATION OF GRAVITY ENERGY STORAGE HYDRAULIC MODELING

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Abstract

Energy storage is widely believed as a solution to the high integration of renewable energy technologies. As more renewable energy systems are deployed, there will be an increasing need for more energy storage. So far, pumped hydro storage (PHS) is considered the most significantly used storage technology. Investors are looking for systems able to overcome PHS drawbacks. As an alternative to PHS, gravity energy storage is a system that is currently under development. This technology is based on PHS working principle. The modeling and simulation of this system is the subject of this paper. This work focuses on the hydraulic dynamics of the system. Since gravity energy storage requires complex fluid and structural systems, a mathematical model has been developed using Simulink to investigate the system performance. The proposed model has been validated experimentally. The results obtained from the performed simulation allow for the identification of important parameters such as duty cycle time, piston position, chambers pressure and volume, as well as quantification of the system power and capacity. It is demonstrated that the simulated model can successfully mimic the operation of a real model with relatively small errors.

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Keywords: Hydraulic modeling; gravity storage ; enegry storage; dynamics

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1. Introduction

Towards the achievement of ambitious plans to decarbonize the energy production system and ease the dependence on fossil fuel, energy storage will undergo significant changes in the coming years. Renewable energy generation is projected to play an important role in achieving these targets [1]. Therefore, a set of objectives need to be ensured which include energy affordability, security, and sustainability. Due to the variability of renewable energy sources, they are considered less effective in meeting energy demand. Therefore, energy has to be held in reserve in order to ensure security of energy supply. To balance the energy demand and supply, several solutions exist among them; enhancement of the grid network, energy load shifting, and energy storage [2]. This latter is considered one of the best options as it could solve several challenges resulting from the high integration of renewable energy. A well proven storage technology that is commonly used is pumped hydro storage (PHS). However, such a system needs specific height difference which is not always available. Based on the well-established concept of this storage system, several types of hydraulic energy storage systems are under development among them gravity energy storage [3]. This system has similar high efficiency as PHS and is considered robust with a long lifetime [4-5]. In this technology, electricity is stored in the form of potential energy by pumping water up and lifting a heavy piston. During the generation mode, the high pressured water is passed through a turbine by releasing the piston down [6]. A schematic of gravity energy storage is shown in Fig. 1.