



A review of seasonal pumped-storage combined with dams in cascade in Brazil



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ABSTRACT

In order to maintain greater control over the country's water resources and reduce the vulnerability of the Brazilian electricity sector, this paper presents a review of the Seasonal-Pumped-Storage (SPS) potential in Brazil, its benefits and the different ways in which SPS can be integrated with hydroelectric dams in cascade downstream. In addition to increasing the Brazilian energy storage potential, SPS has the potential to: regulate river flows allowing the control of hydropower generation; reduce the spillage and increase power generation in the hydroelectric dams in cascade; turn the construction of new dams more viable where there is no suitable geology for the construction of conventional storage reservoirs; control floods when the geology does not permit the construction of storage reservoirs; decrease the evaporation of accumulation reservoirs; store the electricity generated from intermittent renewable sources; store energy for peak generation; reduce transmission bottlenecks; decrease the cost of electricity transmission from hydroelectric plants in the Amazon; decentralize the energy storage capacity in Brazil to increase energy security and to reduce the risk of electricity rationing.

1. Introduction

Brazil has just come out of a severe energy crisis and several regional water crisis, which started in 2013 and lasted until the end of 2015. The level of the stored energy in the reservoirs was reduced to 19% of total capacity in January 2015 [1]. The energy crisis resulted in an average 52% increase in electricity prices between October 2014 and October 2015 [2], which influenced on worsening the economic crisis in the country. In the end of 2015, the rain returned to the South of Brazil and an average of 3 GWmed¹ of hydropower potential bypassed the dams without generating electricity in the Iguacu River during 4 months. As the economic crisis reduced the electricity consumption in 2015 by 0.6% in comparison to 2014 [1], it is expected that more water will bypass the dams in 2016 without generating electricity due to the low electricity demand during the next few years. The electricity supply and demand imbalance will worsen with the operation of new dams in the Amazon that will generate most of their energy during the wet period [3]. The Government has stated that there is the need to increase the storage capacity [4], however no viable solution to increase the countries energy storage potential has been proposed. Electricity demand is set to increase by 44.9% and energy storage will increase by only 0.9% over the next 10 years [4].

An efficient solution to the frequent variation between low elec-

tricity generation and excess of energy for any country is to increase its energy storage capacity. This paper develops and discusses different projects for the implementation of Seasonal-Pumped-Storage (SPS). SPS is an innovative technology, firstly proposed in Hunt et al. 2014 [5,6], to increase energy storage in a seasonal fashion. It stores potential energy during the wet season, when there is excess flow in the river, or when there is excess energy in the grid, pumping water to an upper reservoir. During the dry season, or when there is lack of flow in the river, or when there is lack of energy in the grid, the stored water generates electricity in the SPS and in the dams in cascade (two or more hydroelectric dams in series). Although, a conventional pumped-storage plant has an average energy efficiency of 75%, the combination of a SPS with hydropower dams in cascade, can increase the total storage efficiency to around 90%, without including the reduction of spillage in the dams in cascade. In cases where a SPS decreases the spillage or evaporation in the hydropower dams in cascade, the SPS may result in an overall energy gain, rather than a loss, to the system.

The aim of this paper is to review the potential of SPS in Brazil, the different approaches of combining SPS and dams in cascade, and further benefits of SPS, such as, reduce the vulnerability of a country's energy and water sectors, increasing its energy and water storage capacity; decentralize the storage potential of Brazil, increase the security of the electricity sector, remove the intermittency of renewable

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¹ 1GWmed is equivalent to an average generation of 1GW during a month.