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Enhanced-Pumped-Storage: Combining pumped-storage in a yearly storage cycle with dams in cascade in Brazil

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ABSTRACT

The new frontier for hydropower electricity generation in Brazil, the Amazon region, cannot be used for energy storage as the construction of storage reservoirs would have deep environmental and social impacts, thus run-of-the-river dams have been built instead. If Brazil still wants to generate 80% of its electricity from hydropower, there is the need to increase the country's energy storage capacity so that the excess generation coming from the dams in the Amazon region during the wet period can be used during the dry period. This article presents four ways to increase the storage capacity of a watershed. The most innovative alternative involves a large-scale pumped-storage site combined with a series of hydropower dams in cascade, which could store energy by pumping water to a new reservoir during the wet period and generate energy by releasing the stored water during the dry period. Even though pumped storage schemes have an average efficiency of around 75%, it has been calculated that the combination of a pumped storage site and a series of hydroelectric dams in cascade can increase the overall storage efficiency up to 90% and double the storage capacity of a watershed. This scheme was called EPS (Enhanced-Pumped-Storage).

1. Introduction

Storing energy is a necessity that has come to the attention of various research groups and companies. New technologies such as the hydrogen fuel cell [1] and graphene ultracapacitors [2] are being developed but are not technically mature. Another approach proposed is to use electric car batteries to store electricity through a smart grid system [3]. Reviews of different energy storage technologies and their process description can be seen in Refs. [4,5]. However, almost all bulk generation capacity based on storage schemes, equivalent to over 130 GW [6], comes from PS (pumped-storage) due to its low cost and high energy conversion efficiency (70%–85%) [7,8] and this number is expected to further increase [9].

In Brazil around 80% of the electrical energy comes from hydroelectric power plants – unless there is a shortfall of rain [10]. This is because the combination of varying reservoir dams and run-of-the-river dams in the Brazilian watersheds was designed to generate a constant amount of electricity throughout the year. According to this scheme, during the wet period (December to April) some electricity is generated and some water is stored to fill up storage reservoirs. During the dry period (May to November), the stored water is used to generate electricity and the level of the dams is lowered. This design allows the river to generate a relatively constant amount of energy using the installed generation capacity at a high rate, reducing the cost of electricity.

The approach of relying on a constant hydroelectric generation in the Brazilian watersheds is reaching its feasible limit. Run-of-the-river dams that do not have storage capacity and generate power in proportion to the amount of water flowing in the river, are being built in the Amazon region [11]. This dam building approach is followed mainly because the geological formation of the rivers in the Amazon basin is relatively flat. A large flooded area would be required to store a small amount of energy and during the dry season the devastated area between the forest and the river will be so large that a severe impact to the environment and biosphere will result.

Apart from the lack of generation during the dry period, there is some electricity generation potential wasted as water bypasses dams not generating electricity during the wet period [12]. This waste is expected to increase with the development of the Amazon hydroelectric generation capacity (60% of the Brazilian hydropower potential), as there will be not enough storage capacity to store the

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