Cost-effective design of ringwall storage hybrid power plants: A real options analysis

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Volume 61 (2015). It has been substantially modified and extended, and has been subject to the normal peer review and revision process of the journal.

A R T I C L E   I N F O

Article info
Received 14 November 2014
Accepted 15 June 2015
Available online 23 July 2015

Keywords:
Pumped storage hydro power
Hybrid power plant
Real option
Irreversible investment
Risk and uncertainty

A B S T R A C T

We study the economic viability and optimal sizing and siting of a hybrid plant that combines a ringwall hydro storage system with wind and solar power plants (ringwall storage hybrid power plant, RSHPP). A real options model is introduced to analyze the economics of an onshore RSHPP, and in particular of the varying storage volume in light of the stochastic character of wind and solar power, as well as the optimal investment timing under uncertainty. In fact, many uncertainties arise in such a project. Energy production is determined by the stochastic character of wind and solar power, and affects the optimal size of the storage device. Monte Carlo simulation is performed to analyze the following sources of uncertainty: (i) wind intensity and solar irradiation; (ii) future electricity price; and (iii) investment costs. The results yield the optimal size of the storage device; the energy market on which the operator should sell the electricity generated; numerical examples for two different RSHPP scenarios; and a real options model for analyzing the opportunity to defer the project investment and thus to exploit the value of waiting.

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1. Introduction

Due to the ongoing significant changes in the energy markets, shifting away from fossil and nuclear sources towards renewable energy systems, the contribution of wind and solar photovoltaics (PV) in particular has increased a lot over the last few years. Since this development can be expected to continue, fluctuations in power supply from wind and solar PV are rising as well. To tackle this problem effectively and to balance the load fluctuation, energy storage concepts, especially for the longer-term storage (several weeks instead of just minutes or several hours), are an essential element of energy systems. In recent years, the scientific literature on combining volatile renewables with pumped storage hydro power systems has grown rapidly (e.g. [1–10]). Circular, so-called Ringwall Storage Hybrid Power Plants (RSHPP), which are based on the principle of pumped storage power plants and either constructed as sealed mounds or as mass concrete artificial structures, are an innovative storage concept [11]. A combination of such a storage plant with wind turbines and PV systems can be referred to as an RSHPP (cf. Fig. 1). This paper presents a real options-based model to analyze the economic viability of and the optimal investment timing for an RSHPP in dependence of its stochastically varying energy production and the future evolution of the electricity price.

1.1. A favorable development causing problems

In recent years, the expansion of renewable energies in Europe, and especially in Germany, has progressed rapidly and still does. In 2002, only about 2.7% of the electricity consumed in Germany came from wind and solar power, whereas the contribution of solar power was negligible. By 2012, the share had risen to 12.4%, of...
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