Influence of groundwater exchanges on the efficiency of Underground Pumped Storage Hydroelectricity plants using open pit mines

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Introduction

Underground Pumped Storage Hydropower (UPSH) plants using abandoned mines are an alternative to manage the electricity production. These plants exchange groundwater with the surrounding aquifers (Pujades et al., 2016, Bodeux et al., 2016). The efficiency of pumps and turbines used in UPSH plants depends on the head difference between reservoirs, which is influenced by the groundwater exchanges. Consequently, these exchanges must be considered to improve the efficiency of UPSH plants.

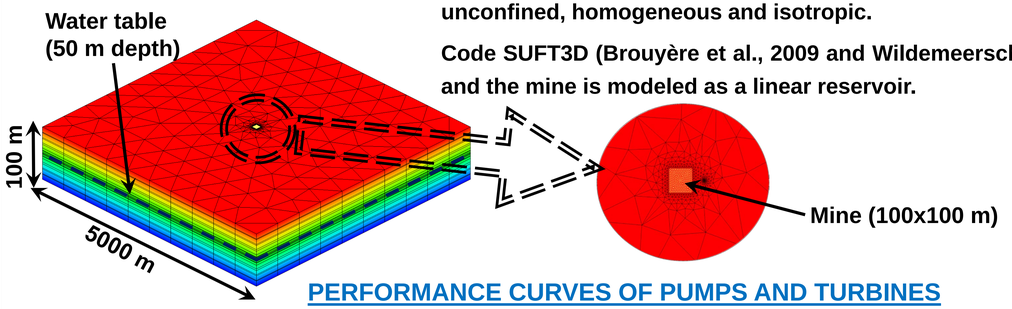
Our goals are to determine the influence of groundwater exchanges on the efficiency, and to assess how the efficiency varies depending on the system properties (aquifer, mine, pumping and injections).

Materials and methods

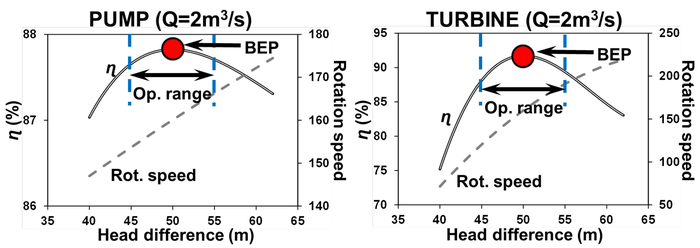
PROBLEM STATEMENT

An UPSH plant made up by an open pit mine is considered. The aquifer is unconfined, homogeneous and isotropic.

Code SUFT3D (Brouyère et al., 2009 and Wildemeersch et al., 2010) is used and the mine is modeled as a linear reservoir.



PERFORMANCE CURVES OF PUMPS AND TURBINES

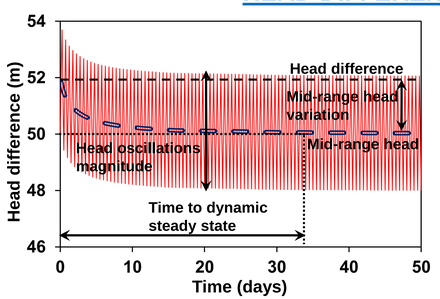


Curves are computed for a constant rate and variable rotation speed.

Max. efficiency is reached when the head difference is 50m.

BEP = Best Efficiency Point

HEAD DIFFERENCE EVOLUTION BETWEEN THE RESERVOIRS

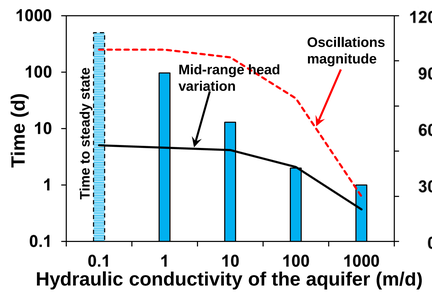


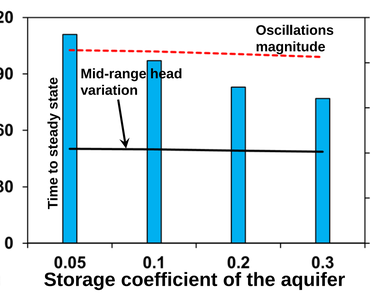
Efficiency varies inside an operation range defined by the head oscillations magnitude. Efficiency is higher when these are lower.

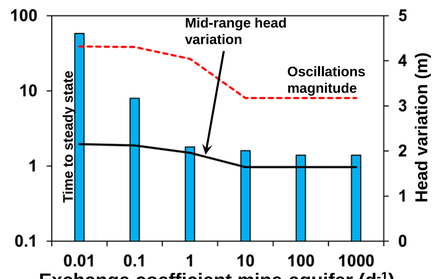
Mid-range head varies over time until the dynamic steady state is reached. Efficiency is higher as lower is the variation of the mid-range head and as faster is reached the dynamic steady state.

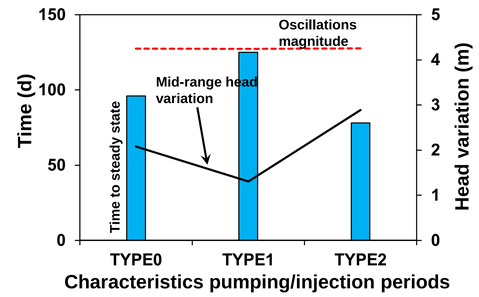
Numerical results of different scenarios (system characteristics are varied) are compared.

Results







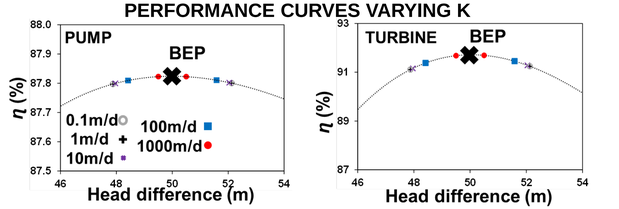


Type 0: Continuous activity

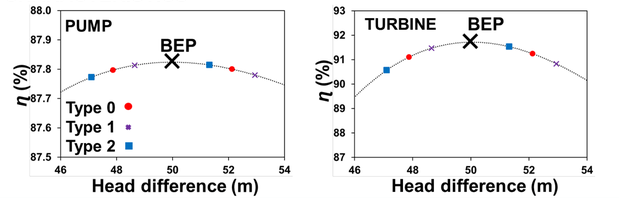
Type 1: 1 day of stop after every two injections

Type 2: 1 day of stop after every two pumpings

PERFORMANCE CURVES VARYING K



PERFORMANCE CURVES VARYING THE PUMPING/INJECTION CHARACTERISTICS



Conclusions

Aquifer properties must be considered in the selection of pumps and turbines of future UPSH plants to improve their efficiency.

Higher groundwater exchanges are beneficial for the efficiency of pumps and turbines but could increase the aquifer impacts. Consequently, it is needed to reach an agreement between efficiency and impacts.

Non-activity periods modify the mid-range head difference. If these are not considered, pumps and turbines could operate far from their BEPs.

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