Short-Term Hydro Scheduling considering the Head Change Effect: Nonlinear Optimisation Methodology

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Abstract

In this communication a methodology based on nonlinear optimisation is presented for short-term hydro scheduling taking into account the head change effect. This methodology considers not only that power generation is a function of water discharge and head, but also that the maximum water discharge is head-dependent, in order to benefit exploitation efficiency. Moreover, a case study is presented illustrating the results comparatively to a methodology based on linear optimisation, which ignores the head change effect.

Keywords: Hydro scheduling, head change effect, nonlinear optimisation.

1. Introduction

The Portuguese fossil fuels energy intensity is among the highest in the European Union. Hence, in order to decrease fossil fuels energy intensity, enhancements in the exploitation of the endogenous and renewable energy resources are particularly important nowadays.

In hydropower plants with a small storage capacity available, also known as run-of-the-river hydropower plants, the power generation efficiency can change significantly due to the head change effect [1]. Hence, it is necessary to consider the head change effect on short-term hydro scheduling in order to obtain results that are more realistic and profitable.

Dynamic programming is among the earliest methodologies applied to the short-term hydro scheduling problem [2]. Although dynamic programming can handle the nonlinear characteristics present in the hydro model, its direct application for hydro systems with cascaded reservoirs is impractical due to the well-known curse of dimensionality, since the computational burden increases exponentially with problem dimension.

A natural approach is to model the hydro system as a network flow model, because of the underlying network structure subjacent in cascaded reservoirs. The network flow model is often simplified to a linear or piecewise linear one [3]. Linear programming is a widely used methodology for short-term hydro scheduling. However, linear programming implies that power generation is linearly dependent on water discharge, thus neglecting the head change effect to avoid nonlinearity, leading to inaccuracy.
Artificial intelligence methodologies have also been applied to the short-term hydro scheduling problem, namely, neural networks [4] and genetic algorithms [5]. However, due to the heuristics used it is not possible to ensure optimal solutions. A few years ago, mixed-integer linear programming was proposed for the short-term hydro scheduling problem [6]. However, the discretisation of the nonlinear dependence between power generation, water discharge and head, used to model head-dependent reservoirs, augments the computational burden required to solve the problem. A nonlinear optimisation methodology has advantages compared with a linear one. This methodology expresses hydro generation characteristics more accurately and the head change effect can be taken into account [7].

We propose a nonlinear optimisation methodology to solve the short-term hydro scheduling problem considering the head change effect. Finally, we present a case study for short-term hydro scheduling with three cascaded head-dependent reservoirs and a time horizon of 168 hours on an hourly basis.

2. Problem formulation

The main goal in the short-term hydro scheduling problem is to maximise the value of total hydroelectric generation throughout the time horizon, typically of one day to one week discretised on an hourly basis, while satisfying all hydraulic constraints. In our methodology, power generation is considered as a nonlinear function of water discharge and water storage. Hence, the effect of the variation of the head is considered. Moreover, the maximum water discharge is considered as a function of water storage, thus head dependent.

3. Case study

We consider a case study for short-term hydro scheduling based on one of the Portuguese hydro systems, consisting of three cascaded head-dependent reservoirs, and a time horizon of 168 hours. The methodology was developed and implemented on a 600-MHz-based processor with 256 MB of RAM using MINOS language. Finally, we present the computed 168-hours optimal storage and discharge trajectories for the proposed nonlinear optimisation methodology, considering maximum water discharge as head-dependent. A comparison with a linear optimisation methodology, disregarding the head change effect, illustrates the merit of the proposed methodology.

4. Conclusions

This paper proposes a nonlinear optimisation methodology to solve the short-term hydro scheduling problem considering the head change effect. A generating company should not ignore the head change effect for run-of-the-river hydropower plants. This effect implies not only a nonlinear dependence between power generation, water discharge and head, but also implies that the maximum water discharge is a function of the head. Our methodology has been successfully tested on a case study by comparing the nonlinear optimisation results with linear optimisation results. The results presented in the case study are consistently in favour of the proposed methodology, achieving an augmented total profit with an acceptable extra computation time.
References


