

# Deterministic hydropower management of large power systems

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**Abstract** – In this paper, we present a new algorithm framework for the robust solution of a deterministic hydropower management problem, where the objective is to maximize the potential energy of the reservoirs while satisfying all operating constraints over a short-term planning horizon. The algorithm is based on the discrete maximum principle.

In order to improve the performances of the proposed algorithm, we have suggested subdividing the short term planning horizon to shorter study horizons so shorter study periods are embedded in a longer one. Afterward, the objective becomes maximizing the value of potential energy stored at the end of the shorter horizon. The final state of the shorter horizon will be regarded as the initial state of the next shorter horizon and so on. Hence, a reduced size problem is solved in each shorter horizon. Consequently, the calculation effort is decreased considerably and moreover it makes easy the adjustment of the parameters of the methods used.

**Keywords:** hydropower management, short-term horizon, potential energy, discrete maximum principle, augmented Lagrangian method, discretized horizon

## I. INTRODUCTION

The hydropower management along a short-term planning horizon is a determinist problem [1] [2], which consists in determining the amount of water to be discharged from each reservoir of the system over the defined planning horizon so that to meet the hourly load demand assigned previously. The prime objective here is to perform the operation policy with the lowest use of water; which is achieved by avoiding spilling and by maximizing the hydropower generation, besides satisfying all operating constraints. The maximization of electrical power production is achieved by maximizing the heads. Consequently, this allows maximizing the reservoirs content.

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horizon will be regarded as the initial state of the next shorter horizon and so on. Hence, a reduced size problem is solved in each short period.

When modelling the problem, and for more accuracy, the following factors which make the problem more complex are taken into consideration; significant water travel time between reservoirs, the multiplicity of the input-output curve of hydroelectric reservoirs that have variable heads, the maximum generation of the hydropower plant varies with the hydraulic head i.e. the quantity of water required for a given power output decreases as the hydraulic head increases, the water stored in the upstream reservoir is more valuable than that stored in the downstream reservoir, whether the reservoirs have very different storage capacity and whether the system has quite complex topology with many cascaded reservoirs.

To solve the deterministic hydropower management problem, we use the discrete maximum principle [3-4]. While solving the equations relating to the discrete maximum principle, we use the gradient method [3]. However, to treat equality constraints we use Lagrange's multiplier method. To treat the inequalities constraints we use the augmented Lagrangian method [5].

Furthermore, the present paper is concerned also with the treatment of the constraints on the state variables, which are of two-sided inequalities. The augmented Lagrangian method is proposed to deal with this type of inequalities.

The hydroelectric power system considered in this paper consists of ten reservoirs hydraulically coupled, i.e., the release of an upstream reservoir contributes to the inflow of downstream reservoirs. All reservoirs are located in the same river. The time taken by water to travel from one reservoir to the downstream reservoir [8-10] and the water head variation are taken into account. The natural inflow and the demand for electrical energy are known beforehand. The scheduling is stretched over one week divided into days; the days are subdivided into hours.

The decision variables in the optimization problem are the amount of water to be released from each reservoir to their direct downstream reservoirs in a