2006 IEEE PES Transmission and Distribution Conference and Exposition Latin America, Venezuela

Short Term Security Constrained Hydrothermal Scheduling Considering Transmission Losses

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Abstract— **This paper proposes a Dual Dynamic Programming (DDP) approach to solve a network constrained short term hydrothermal scheduling problem with transmission losses. The DDP methodology, contrary to traditional dynamic programming approaches, approximates the cost−to−go function for each stage by a multistage Benders decomposition. In order to consider the electrical network in detail, an inner loop is performed to solve every stage, where the (quadratic) DC model losses for each line are approximated by a piecewise linear function. Line capacities are also considered. The hydro system is represented in high detail. It includes cascaded reservoirs, several hydraulic constraints and an accurate representation of hydro generation as a multi−dimensional piecewise linear function of storage, turbine and spillage. To assess the approach, a study case based on an IEEE 118 bus system is performed. Convergence properties and the optimal dispatch are compared whether the transmission losses are taken or not into account. The accuracy of the approach proposed is verified. Preliminary studies with the whole Brazilian System is also presented.**

Index Terms-- **Power generation scheduling, security constraints, transmission losses, Benders decomposition.**

I. Introduction

THE operation planning of hydrothermal systems, usually called Hydrothermal Coordination (HTC), is a very complex optimization problem. Decisions to be made are coupled in time, as future reservoirs storages depend on the previous operation of the system. Generations of hydro and thermal plants must be coordinated, not only because of system constraints such as satisfaction of demand and reserve, but also because of plant operation characteristics, such as hydro plants in cascade. In addition, uncertainties of both demand and hydrological conditions have to be managed.

The HTC problem is usually solved by decomposition of the original problem into long, medium and short term problems [1], [2], each one considering the appropriate aspects for its time step and horizon of study. In general, uncertainties are modeled accurately in the long run, while system constraints are more detailed in the short term horizon. Coordination among the models that solve each problem can be done by primal or dual approaches. As an example of the first case, for example, the mid term model can set for the short term model final volume targets for the reservoirs [3], or weekly average discharge [2] or generation [4] targets for the hydro plants. In the dual approach, an economic value is assigned to the water in the reservoirs, through individual marginal prices [5] or by a Future Cost Function (FCF) that expresses system operation costs in the future as a function of the storage in the reservoirs [1], [6].

CEPEL, the Brazilian Electric Power Research Center, has developed a chain of optimization models for the optimal planning and operation of hydrothermal systems which has been used for setting the energy dispatch and spot prices in the Brazilian electrical system [1]. In CEPEL's optimization chain, the solution strategy to solve the HTC problem is dual dynamic programming (DDP) [7]. As a by-product of this solution technique, a system FCF built by each model becomes available for use at the end of the horizon of the subsequent model in the chain. The use of a FCF has the advantage of avoiding setting generation and / or discharge targets for the plants at the downward model. This is important because these targets may become non-economical or unfeasible due to the more detailed constraints considered in the subsequent model.

The problem described in this paper is related to the short term model of this optimization chain, DESSEM [8]. This model addresses the optimal hourly dispatch problem within 1 week. A DC model for the electrical network and line capacities are considered, as well as a variety of constraints for the reservoirs and power plants. An accurate modeling of the hydro plants power production as a function of turbined flow, storage and spillage [9] is also included.

A. Short Term Hydrothermal Scheduling

The short term hydrothermal scheduling problem (STHTS) has been extensively study over the last 60 years. It can be considered as the main problem [6]-[9], [10], [11] or can be originated from decompositions to a larger problem with hydro or thermal unit commitment constraints. In the latter case, Benders decomposition [3], [12], [13] can be applied to obtain a mixed-integer master problem for the units status and a continuous subproblem for the generation dispatch. Lagrangian [14], [15] and augmented Lagrangian [16] relaxations have also been proposed to obtain separated hydro and thermal subproblems, coordinated by a dual solution procedure. The hydro subproblem can be solved by Network Flow Programming [10], [15], while for thermal subproblems

The authors acknowledge the financial support given by CEPEL, the Brazilian Electric Power Research Center.

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1-4244-0288-3/06/$20.00 ©2006 IEEE