

# SHORT TERM HYDROTHERMAL COORDINATION PROBLEM CONSIDERING ENVIRONMENTAL CONCERNS

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**Abstract**— Solving the Short Term Hydrothermal Coordination Problem considers the resolution of both the Unit Commitment and the Economic Dispatch for thermal and hydraulic units. This problem is solved for several time horizons between a day and a week with a one-hour step. The traditional short-term scheduling problem of hydrothermal units, minimizing fuel cost during a time, does not include concerns due to emission pollution coming from the operation of thermal plants. In this work, environmental constraints are considered. Focusing on avoiding post-dispatch corrections, the transmission network is modeled with a high level of detail considering an AC power flow. These facts lead to a very complex optimization problem which is solved by using a novel decomposition approach based on Generalized Benders Decomposition and traditional, well-known optimization techniques. The approach presented in this work allows the decomposition of the whole problem in a quadratic mixed integer master problem, and in a separable non-linear subproblem. The former defines the state and the active power dispatched by each unit whereas the latter determines the reactive power to meet the electrical constraints through a modified AC optimal power flow. Different variations of the developed methodology were evaluated in order to consider environmental constraints. These approaches were applied to a 9-bus test case and to a 87-bus real system.

**Keywords**— Short Term Hydrothermal Coordination, Unit Commitment, Generalized Benders Decomposition, Environmental Constraints.

## I. INTRODUCTION

Short Term Hydrothermal Coordination Problem (STHTC) considering a centralized dispatch has been used world-wide, especially in Latin-America (Sifuentes and Vargas, 2007a). Solving this problem defines the operation state and power level of each

generation unit (thermal and hydraulic) of an interconnected power system achieving the lower operative cost, satisfying technical and operative constraints of generators and transmission network, among others.

Although the use of clean generation technologies is growing nowadays, fossil fuels represent a reliable and affordable source of energy, necessary to satisfy the demand for electric energy. Economies based on fossil fuels has brought with it the potential harmful problem of the emission of gaseous and particulate products of combustion, which when reaches a pre-specified threshold, is termed pollution (Bellhouse and Whittington, 1996). Environmental concerns are becoming increasingly relevant for companies as regulations on pollutants become more stringent, therefore these concerns must be considered in scheduling models.

Conventional power generation plants causes pollution through the emission of several gases into the atmosphere. Among these gases are carbon dioxide (CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>) which have a global environmental impact (greenhouse effect) and local effects such as acid rain and reduced visibility among others. In this work, environmental concerns are considered as a cost given by quadratic functions of thermal power generated by each unit. These functions are used to penalize the amount of emission of each gas.

The STHTC problem without considering environmental constraints has been studied considering different formulations and using different resolution techniques. The simpler ones, which consider basic models which do not represent real characteristics of electric systems, are the starting point of this research field. Among the more basic formulations is the one presented in Wood and Wollenberg (1984), which is an academic approach that only considers thermal units and is solved using a merit order list. This means that the units are dispatched in increasing cost order by Megawatt produced. This procedure is quite different from the one used in real systems as it does not take into account inter-temporal constraints (such as minimum periods of operation of thermal units or the consideration of start-up costs); or the fact that not always the thermal generation units operate at a constant power level. Other techniques, ranging from clas-