Unit Commitment with CO2 Emissions Limits: A Multi-objective Approach

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Abstract: Ecuador as a country has started to become concerned about quantifying CO2 emissions, and it has been verified that this factor has increased over the years, depending in part on the hydrology observed in the Ecuadorian Electricity System. Incidentally, the execution of hydroelectric projects that are in need of a significant investment of capital could be promoted with carbon credits, by taking these emissions into consideration. It is therefore important to begin bearing these environmental factors in mind for the system’s operation. This paper deals with the problem of committing units when emissions limits are taken into consideration. A multi-objective model is suggested which deals with both economic factors and CO2 emissions limitations. An example is presented in order to make comparisons between the traditional unit commitment model and the proposed method, and to observe the feasibility of applying this methodology.

Keywords: Unit Commitment, Multi-Objective Programming, CO2 Emissions, Goal Programming.

1. Introduction

The Kyoto Protocol on climate change is both a protocol and an international agreement of the United Nations Framework Convention on Climate Change, whose aim is to reduce the six greenhouse gases responsible for global warming: Carbon Dioxide – CO2, Methane – CH4, Nitrous Oxide – N2O, Hydrofluorocarbons – HFC, Perfluorocarbons – PFC and Sulfur Hexafluoride – SF6, by an approximate percentage of at least 5%, from the period beginning in 2008 through 2012. Such reduction must be accomplished in comparison with the emissions of year 1990. The protocol was initially adopted on December 11, 1997 in Kyoto, Japan, and entered into effect on February 16, 2005. In November of 2009, 187 nations ratified the protocol, among them Ecuador.

In Ecuador, the growth rate for total CO2 emissions between years 1994 and 2003 was 4% (Nina, 2010). Conversely, the CO2 emissions factor of the Ecuadorian National Interconnected System ex-ante year 2011, within the combined margin of thermoelectric and hydroelectric projects, was 0.5531 tCO2/MWh.

The Clean Development Mechanism or Mechanism for Clean Development, CDM, is an agreement contained in article 12 of the Kyoto Protocol. This allows both governments and companies in industrialized nations to sign agreements for complying with Greenhouse Gases (GHG) goals, by investing in emissions reduction projects in developing countries as an alternative, in order to obtain Certified Emission Reductions (CER) at lower costs than in their own respective market(s). The CDM allows for the possibility of transferring clean technology to developing countries. Once governments or companies invest in CDM projects, they receive certified emissions reductions -CER (one of the three types of compliance carbon credits). These investments signify a lower cost than that of obtaining them in their own respective markets, and simultaneously serve to help meet the reductions goals that they are committed.

In the electricity sector, emissions reduction projects are related to renewable energy projects (biomass, wind, solar and hydraulics). In Nina (2010), a change to the Energy Mix is established as an energy strategy for the country. One of this strategy’s components is increasing the participation of renewable energy: the completion, without delay, of hydroelectric projects that fall under the Electrification Master Plan, and promoting renewable energy projects. It is therefore of paramount importance during the unit commitment process, to be mindful of those units that take CO2 reductions into consideration.

The relevant references for this study differ in both their objectives and the form in which they solve the problem. For Catalao (2007), the Unit Commitment problem’s objectives are to minimize earnings from energy sales and as an objective in comparison to this, minimize the emissions due to generator running, and the model proposed for this purpose is solved by the convex combination of the two objectives using Mixed Integer Linear Programming – MILP. The method by Kockar, (2008) considers the combined minimization of production costs and emissions costs subject to emissions limit restrictions and is resolved with MILP. Finally Raglend and Padhy (2006) also considers the combined minimization of production costs and emissions, while considering the emissions as a penalty factor. The model is resolved using an algorithm that is specifically designed to solve the problem being processed.