Unit Commitment problem with uncertain demand and renewable energy availability

Cristian Aguayo[1,3] and Bernard Fortz[2,3]

[1]Département d'Informatique, Université libre de Bruxelles, Brussels, Belgium
[2]HEC Liège, Management School of the University of Liège, Liège, Belgium
[3]INOCS, INRIA, Villeneuve d'Ascq, France

Abstract: Energy generation is an area where four of the many problems facing humanity today - the energy crisis, climate change, scarcity of natural resources and global warming - interact in a vicious circle. In this scenario, it is not surprising that governments around the world are reviewing their energy policies. Agents such as Renewable Energy Sources (RES) and Local Energy Communities (LEC) can play a fundamental role in the energy transition. However, the optimization of operational costs continues to be a relevant factor. The Unit Commitment (UC) problem is one of the classical approaches to optimize these costs. This problem involves decisions related to the schedule of generating units as well as the power they must produce in order to meet the total power demand, where the last one can be deterministic or uncertain. By integrating RES, a new source of uncertainty is added to the problem. In this work, various formulations for the UC problem with uncertainty are presented and solved using benchmark data.

Keywords: Robust Optimization, Mixed Integer Linear Programming, Energy

1 Introduction

The Unit Commitment (UC) problem is one of the classical approaches to determine which generators should be switched on or off in a given period and how much power they would dispatch over a short or medium-term time horizon, subject to sets of constraints such as demand meeting, minimum up and down times, and minimum and maximum power output. Usually, the UC problem is used to optimize the power generation of thermal and hydrothermal units [7, 5, 3], but there are also applications of this model for cases with renewable energy sources, either with or without the presence of hydrothermal generating units [4, 6]. The UC problem is often formulated as a mixed integer program (MIP), which can be linear (MILP) or non-linear (MINLP). The UC problem involves decisions about turning on or off generators belonging to a set $\mathcal{J} = \{1, 2, ..., J\}$ during a certain period, and how much power they will produce. On and off decisions are represented by binary decision variables, while power generation in represented by continuous decision variables. Usually, the time horizon is represented by a discrete set $\mathcal{K} = \{0, 1, ..., K\}$ of periods. In a very general way, some of the constraints of the UC problem are:

- Power demand meeting for each period: each period, the power produced by all the generating units that are on should be able to satisfy the power demand.
- Minimum up and down constraints: depending on the nature of the generating units, they may have a minimum operating time after being turned on, as well as a minimum idle time after being turned off.
- Ramping constraints: these constraints model the fact that a generating unit cannot drastically increase or decrease the amount of generated power.

Since the UC problem must ensure that energy demand is met, energy demand forecasts play a fundamental role in solving real-life economic dispatch problems. When considering Renewable Energy Sources (RES), forecasts related to the availability of these intermittent energy sources must also be considered, so it is necessary to have tools to efficiently handle the randomness in the UC problem. This paper focuses on presenting and solving different UC models with uncertainty in energy demand and availability of dispatchable renewable energy.

2 Methodology

Two groups of UC models can be found in literature. The first one is the Single Bus UC (SB-UC), in which the aggregate energy demand must be satisfied, and the second is the Multi Bus UC (MB-UC), where the demand of each bus must be satisfied separately. The main difference between these groups of models is that MB-UC considers that energy flows through transmission lines, which have a limited capacity of energy flow,which implies that the UC problem acquires a network structure by adding the decision of how much energy flows from one bus to another.

To deal with uncertainty, the robust optimization approach was adopted. Robust optimization considers a set of uncertainty over which the objective function is optimized, taking into account that feasibility must be maintained for all possible values of the uncertain parameters. To avoid that the solutions obtained are too conservative, an uncertainty budget is usually considered, which allows adjusting the level of conservatism of the solution [2]. For the UC problem with uncertain demand and RES availability studied in this paper, each source of uncertainty has its own uncertainty budget parameter.

Two techniques were implemented to solve de robust model: Affine Decision Rules (ADR) [1], and Column and Constraint Generation (CCG) [8]. The proposed models and the proposed techniques were tested on instances based on the IEEE multi bus instances available in the MATPOWER package repository for `MATLAB`.

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