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Mixed Integer Linear Programming for new trends in wind farm cable routing

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Abstract

The efficient production of green energy plays an import role in modern economies. In this paper we address the optimization of cable connections between turbines in an offshore wind park. Different versions of this problem have been studied recently. In a previous joint project with Vattenfall BA Wind (a global leader in energy production) we have studied and modeled the main constraints arising in practical cases. Building on that model, in the present paper we address new features that have been recently proposed by Vattenfall's experts. Turbines are becoming still more customized, therefore it is important to be able to evaluate the impact of new technologies with a flexible optimization tool. We here show how some new features can effectively be modeled and solved using a Mixed-Integer Linear Programming paradigm. Computational results on a real-world case are briefly presented.

Keywords: Network models, wind farm optimization, mixed-integer linear programming, computational analysis.

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1 Introduction

The production of green (in particular, wind) energy is an important topic both in industry and academia. As modern wind parks are getting bigger in size and in produced power, it is very important to optimize their design.

In this paper we address the optimization of cable connections among offshore turbines, called *cable routing* in what follows. Different versions of this problem have been studied in the recent literature, including [2,3,4,5,7]. Thanks to the collaboration between Vattenfall BA Wind (a global leader in energy production) and Technical University of Denmark (DTU), in the last couple of years we have been able to identify the constraints that arise in practical cases—some of which were missing in previous work from the literature. In particular, in [6] we introduced a new solution framework based on a Mixed-Integer Linear Programming (MILP) model, which is solved either exactly (through a commercial MILP solver) or heuristically (through an ad-hoc matheuristic scheme). The resulting optimization tool has been validated by Vattenfall's experts, and is routinely used by the planners. The tool is able to cope with practical needs such as the possibility of curvy cable connections, the need to avoid obstacles in the site, and power losses; see [6] for further details.

Thanks to our ongoing collaboration with Vattenfall, we have a continuos feedback from experts on the new problem specifications arising from new projects. In the present paper, we address new features of great importance, and show how they can be modeled and solved using MILP technology. In particular, we address three main extensions of the MILP model given in [6], that allow us to enforce a "closed loop" structure intended to handle possible cable failures, to penalize in a nonlinear way the number of cables entering each turbine, and to use the emergent *Offshore Transformer Module* technology [8] to replace substations.

The paper is organized as follows. The basic model proposed in [6] is briefly summarized in Subsection 2.1, while the three extensions are addressed in Subsections 2.2, 2.3 and 2.4, respectively. Section 3 finally reports computational results on a real case.

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