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Optimal management of power generation assets: Interaction with the electricity markets

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Abstract

For historical reasons, many large industrial sites have their own power generation units, whether it is because the site was isolated when built up or the local network wasn't reliable enough to ensure a regular production. This can apply for energy-intensive industries like refineries or LNG plants in the Oil & Gas sector, but also mining plants, metal industries or chemical plants for instance. These generation assets are usually operated in a suboptimal way, the only concern being the safety of the process. The gist of this work will be to determine an optimal use of these assets for the industrial plant operator, considering interactions with the electricity markets.
Laying on the mathematical description of this optimization problem, a model was built up following a double target. First, to develop a standard architecture that would easily be translated from one case to the other. Then, to assess how high the expected savings could go and what would the induced strategy be. This model has been applied to a refinery case study, where the expected earnings rose up to 8 M€ per year. It accounts for 1% of the turnover. The figures obtained show that this is a relevant business concept. Following this trend, other energy-intensive case studies are being considered, from cement plant to paper plant.

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1. Introduction

For historical reasons, many large industrial sites produce their own electricity. Whether it is because the site was isolated when built up or the local network wasn't reliable enough to ensure a regular production, the industrial hence detains the responsibility to manage its own production unit. This

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situation mostly involves energy-intensive industries, as iron/steel or other metal industries, foundries, paper mills, cement plants, chemical plants – and in particular petro-chemical plants including refineries –, or even glass industries. Hence, we have here a situation where the production units are managed by local operators, and where the main goal of these operators is to ensure the industrial site's production. We understand that the decision process for meeting the demand will then often be based on the operators experience and safety concerns, which can easily lead to sub-optimal solutions. In particular, this can lead to a situation where many production units are used below their nominal capacity, leaving a potential unused for energy savings, earnings or environmental purposes [1-3].

We want to determine an optimal use for these electricity generation assets. We will consider these producers taking a role on the electricity markets. Indeed, as these capacities are currently used in a sub-optimal way, interactions with the markets appear to be an interesting way to try to manage them in a more profitable direction that would hence generate extra-earnings. Our problem statement is the following:

> Considering an industrial site with electricity generation assets, considering interactions with the spot markets (sales and purchases) and taking into account operational constraints and constraints from the Transmission System Operator (TSO), what earnings could the industrial get from an optimal use of its assets?

2. Generic Model

2.1. Objective

We will want our model to provide the two following outputs:

- the amount of these potential earnings, to see if this option is relevant or not, and maybe worth investing into;
- the guidelines on how they would be achieved. Although it isn't meant to be a genuine piloting tool, we must show that our solutions are realistic. Hence, our model must still give an idea of how these earnings would be made, what the production curve of each machine would look like.

2.2. General architecture

The model we develop will be based on the architecture displayed Figure 1. The electricity will be produced by either gas or steam turbines, and we shall hence consider both steam and electricity flows. Given the characteristics of the machines and the production planning of the industrial site, we will expect our model to determine the optimal production level of each machine. Comparing the cases with and without interaction with the electricity markets, we will deduce the extra-earnings we generate.

This model lays on a mixed binary-continuous linear optimization problem. The flow variables are continuous, and the decision variables will be the sales and purchases on the markets and the gas purchases [4]. The objective function can hence be written in the equation involving prices (p), commission fees (p_{fee}) and quantities exchanged on the market (q):

$$\max \sum_{t} \left(p_{elec,t} - p_{fee}\right) \cdot q_{sales,t} - \left(p_{elec,t} + p_{fee}\right) \cdot q_{purchase,t} - p_{gas,t} \cdot q_{gas,t} \quad (1)$$

with the following assumptions:

- the production of the regular output of the plant (for instance, refined products in a refinery) is guaranteed;
- the use of the machines follows operational constraints [5]. Specifically, we will consider the inertia of