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# The optimal electric energy procurement problem under reliability constraints

Patrizia Beraldi*[a], Antonio Violi[a], Gianluca Carrozzino[a], Maria Elena Bruni[a]

[a]*Department of Mechanical, Energy and Management Engineering, University of Calabria, via P. Bucci 41/C, Rende (CS) 87036, Italy*

**Abstract**

We consider the problem faced by a large consumer that has to define the procurement plan to cover its energy needs. The uncertain nature of the problem, related to the spot price and energy needs, is dealt by the stochastic programming framework. The proposed approach provides the decision maker with a proactive strategy that covers the energy needs with a high reliability level and integrates the Conditional Value at Risk (CVaR) measure to control potential losses. We apply the approach to a real case study and emphasize the effect of the reliability value choice and the difference between risk neutral and adverse positions.


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*Keywords:* Energy procurement; probabilistic constraints; risk management; stochastic programming

## 1. Introduction

The definition of the optimal procurement plan represents one of the most challenging problem that any consumer, especially if involved in power-intensive activities, has to properly address with the aim of reducing the overall costs. In this paper, we consider the case of a large consumer that owns a limited self-production facility and has to choose the best involvement in the procurement opportunities so to cover its energy needs. Besides self-production, the consumer has the opportunity to procure energy through bilateral contracts, with agreed fixed prices, and the spot market. Bilateral contracts generally provide more effective hedging against the spot price volatility,

* Corresponding author. Tel.: +39-984-494826; fax: +39-984-494730.
*E-mail address:* patrizia.beraldi@unical.it


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but at the expense of higher expected average costs. On the other hand, relying mostly on the market may result in an unacceptable volatility of the procurement costs. Hence, there is a trade-off between the purchasing opportunities that should be carefully evaluated. The decision problem is additionally complicated by the presence of uncertainty that does not only occur in the electricity price, but also, with an even greater impact, in the energy needs. Decisions regarding the commitment to bilateral contracts have to be taken before the actual spot electricity price and energy demands are known and since there is only limited room for reactive actions or they are particularly expensive, it is mandatory to account for these uncertainties in the decision-making process. In this paper, we address the optimal energy procurement problem under uncertainty by adopting the paradigm of the probabilistic constraints, defined within the general stochastic programming framework. Interested readers are referred to the textbook [1] for a detailed description of the stochastic programming paradigms. Some examples of applications in the energy field are reported in [2-9].

**Nomenclature**

***Sets***

| | |
|---|---|
| $T$ | set of months of the planning horizon, indexed by $t$ |
| $F$ | set of time blocks (e.g. peak, intermediate and off peak), indexed by $f$ |
| $S$ | set of scenarios representing the uncertain system evolution, indexed by $s$ |
| $N$ | set of bilateral contracts to evaluate, indexed by $i$ |

***Parameters***

| | |
|---|---|
| $B_{itf}$ | unit price for purchasing energy from bilateral contract $i$ for the time block $f$ of month $t$ |
| $FB_i$ | fixed components related to the activation of bilateral contract $i$ |
| $\pi_s$ | probability of occurrence of scenario $s$ |
| $D_{tf}^s$ | overall demand for time block $f$ of month $t$ under scenario $s$ |
| $P_{tf}^s$ | unit price for purchasing energy from the spot market for time block $f$ of month $t$ under scenario $s$ |
| $R_{tf}^s$ | unit price for selling energy through the market for time block $f$ of month $t$ under scenario $s$ |
| $L_{itf}$, $U_{itf}$ | lower and upper bound on the energy quantity purchased from contract $i$ for time block $f$ of month $t$ |
| $PC_{tf}$ | unit production cost from traditional systems for time block $f$ of month $t$ |
| $Q_{tf}^{max}$ | maximum energy production from traditional systems for time block $f$ of month $t$ |
| $N^{max}$ | maximum number of bilateral contracts to activate |
| $\alpha$, $\beta$ | confidence level for probabilistic constraints and CVaR, respectively |
| $\lambda$ | risk aversion parameter |

***Decision Variables***

| | |
|---|---|
| $x_{itf}$ | energy quantity to buy form bilateral contract $i$ for time block $f$ of month $t$ |
| $y_{tf}$, $w_{tf}$ | amount to buy/sell from/on the market for time block $f$ of month $t$ |
| $Q_{tf}$ | amount to produce with conventional system for time block $f$ of month $t$ |
| $z_i$ | binary decision variable on the selection of bilateral contract $i$ |
| $VaR$ | Value at Risk |
| $CVaR$ | Conditional Value at Risk |
| $G_s$ | "loss" under scenario $s$ |
| $a_{tf}$, $b_s$, $\sigma_s$ | auxiliary variables |

The proposed approach provides the decision maker with a proactive procurement plan that covers the uncertain energy needs with a prescribed reliability level, thus limiting to a very low value the probability of shortage. Moreover, the proposed model accounts for risk in the decision process by incorporating in the objective function the Conditional Value at Risk (CVaR) measure (see, for example [10, 11]) to control the potential losses caused by the random costs. We apply the proposed framework to a real case study and we emphasize, in the analysis of the results, the effect of the choice of the reliability value along with the difference between risk-neutral and risk-averse decision maker positions.