# Reliable microgrid energy management under environmental uncertainty and mechanical failures: an agent-based modelling and robust optimization approach

E. Kuznetsova, C. Ruiz, Yanfu Li, Enrico Zio

# Reliable microgrid energy management under environmental uncertainty and mechanical failures: an agent-based modeling and robust optimization approach

E. Kuznetsova
*International Chair in Eco-Innovation, University of Versailles Saint Quentin-en-Yvelines, Guyancourt, France*

C. Ruiz
*Department of Statistics, Universidad Carlos III de Madrid, Leganes (Madrid), Spain*

Y.F Li[1] & E. Zio[1,2]
[1] *Chair on Systems Science and the Energetic Challenge, European Foundation for New Energy-Electricité de France, Ecole Centrale Paris – Supelec Paris, France*
[2] *Dipartimento di Energia, Politecnico di Milano, Milano, Italy*

ABSTRACT

In this paper, we consider a microgrid system with uncertainties in wind power generation due to environmental conditions and mechanical failures. The system is described by Agent-Based Modelling (ABM). Prediction Intervals (PIs) are estimated to characterize the uncertain environmental parameters of the microgrid working scenarios. The estimation is made by a Genetic Algorithm (GA) – trained Neural Network (Ak et al. 2013), which gives lower and upper prediction bounds between which the uncertain value is expected to lie with a given confidence. Each agent is seeking for optimal goal-directed actions planning. The Robust Optimization (RO) approach (Bertsimas & Sim 2004) is used for searching optimal planning solutions.
For exemplification, we consider a microgrid composed of a middle-size train station (TS), which can play both roles of power producer with photovoltaic panels (PV) and consumer, the surrounding district (D) with residences and small businesses, and a small urban wind power plant (WPP) as renewable power generator. In addition, we assume that TS and D have the capacity to store electricity in batteries.
To formulate the power scheduling problem, the TS, WPP and D agents are represented as 'open systems' that continuously interact with each other through power exchanges at each time step *t*. The hierarchy of decision, considered in this work for exemplification, gives priority to the power generators, i.e., TS and WPP, to decide the renewable power portions available to be sold to D at each time step *t*. These decisions are transmitted through the Independent System Operator (ISO) to D, which considers these decisions as constant parameters for its optimization. The duration of the bilateral contract is assumed to be one hour.
The overall microgrid performance is evaluated in terms of classical adequacy assessment metrics such as Loss of Load Expectation (LOLE) and Loss of Expected Energy (LOEE). To measure the energy management performance of the individual agents, i.e., WPP and D, relative deviations of the optimized revenue and cost functions, $\Delta^{WPP}$ and $\Delta^{D}$, for N time steps are introduced.
The results are obtained by simulation of the agents dynamics for two case studies (Table 1): (a) deterministic optimization based on expected values and (b) RO performed on PIs.

Table 1. Performance indicators.

| # | LOLE, h/τ | LOEE, kWh/ τ | $\Delta^{WPP}$, % | $\Delta^{D}$, % |
|---|---|---|---|---|
| Deterministic | 0.257 | 1.384 | -22.461* | 0.742 |
| RO | 0.002 | 0.0202 | 76.423 | 0.003 |

* Minus indicates the overestimation tendency of the revenues.

RO results in an increase of the reliability of the microgrid, i.e., LOLE and LOEE indicators decrease their values, and an increase of the conservatism in the energy management, which is reflected in the different behaviours of the cost and revenue indicators denoted $\Delta^{WPP}$ and $\Delta^{D}$. In the deterministic case, $\Delta^{WPP}$ takes negative values, i.e., revenues are overestimated due to the small coverage probability of the wind power output predictions. On the contrary, RO leads to increasing positive values of $\Delta^{WPP}$, i.e., underestimated costs.
RO implies a smaller error $\Delta^{D}$ because even in presence of prediction errors, the WPP is committed to supply the agent amount of power to D. However, in some exceptional cases, e.g., of mechanical failures of the generator, such power cannot be supplied. In this sense, RO of available wind power output leads to energy management decisions which are robust against the uncertainty in wind power supply to D.

REFERENCES

Ak, R., Li, Y.F., Vitelli, V. & Zio, E., 2013. Multi-objective Generic Algorithm Optimization of a Neural Network for Estimating Wind Speed Prediction Intervals. submitted to Renew. Energ.

Bertsimas, D. & Sim, M., 2004. The Price of Robustness. Operations Research, 52(1), pp.35–53.