DAILY DECISION MODEL FOR INDUSTRIAL ENERGY FLEXIBILITY CONSIDERING ECONOMIC RISK THROUGH CONDITIONAL VALUE-AT-RISK

Isabella BIANCHINI[1], Lea BITTEROLF[2], Alexander SAUER[3]

Introduction

The integration of renewable energy generation poses challenges to the electricity system management [1]. Additional flexibility on the demand side is required to guarantee the balance between generation and demand [2]. In addition, the increased and more volatile electricity prices experienced in Europe since 2022 are causing higher energy costs for the industrial companies, which have to take decisions on their production and investment plans facing an unpredictable production costs development [3]. Energy flexibility of industrial systems can help the energy system to maintain the system stability [4]. Moreover, it contributes to the reduction of production costs and to the competitiveness of the industrial sector [2]. The so-called energy flexibility measures (EFM) are scheduled one day in advance in order to exploit the potential for energy cost reduction and combine it with production planning [5, 6]. Scheduling in advance results in uncertainties in the decision taking, and thus corresponding economic risks [7]. Understanding risks is crucial for industrial companies as they must be aware of potential losses when taking decisions [7]. Conditional value-at-risk (CVaR) is a very powerful risk measure [8]. It represents the average losses after a defined confidence level and can be included in linear programming for optimal decision making [8]. CVaR needs probabilistic forecasts of uncertain variables as input and is sensitive on scenarios modelling coming from distribution functions [9]. Previous work showed the potential of the CVaR combined with the scheduling of energy flexibility [7]. However, the optimization was not carried out for the entire day, and local minimum were being targeted. In addition, the effect of different scenarios modelling on the results has not been fully investigated.

Method

This paper proposes a decision model based on daily stochastic optimization of EFM activation planning considering the potential economic losses. The optimization considers one day and includes two parts. The first part considers the cost variation due to variable electricity prices, while the second part corresponds to the CVaR. The company´s risk appetite, i.e. the willingness to risks for achieving certain goals, is modelled through parameter omega. The industrial company can decide according to the current risk appetite and compromise between the potential optimal cost reduction for the following day and the economic risk. The decision model includes the EFM technical constraints and constraints on the maximum power at the connection point, to ensure that grid charges are not higher than before the optimization. The EFM considered in the use case are electrical vehicles (EV), an energy storage system (ESS) and a compressed air storage system (CAS). The prices are included as probabilistic scenarios, which are extrapolated from cumulative distribution functions based on historical data (Figure 1). The second part of the paper assesses the sensitivity of the proposed daily decision model towards different probabilistic models using different distribution functions for electricity prices (Figure 1). The characteristic parameters of the chosen distribution functions (normal distribution, t-Location-Scale distribution, gamma distribution and lognormal distribution [10]) were defined on the basis of historical data. Afterwards the price scenarios were extrapolated and used as input in the decision model.

[1] Fraunhofer Institute for Manufacturing Engineering and Automation IPA, Nobelstr. 12, D-70569 Stuttgart, +49 (0)711 970-1959, isabella.bianchini@ipa.fraunhofer.de, www.ipa.fhg.de
[2] University of Stuttgart Institute for Energy Efficiency in Production EEP, Nobelstr. 12, D-70569 Stuttgart, st180049@stud.uni-stuttgart.de, www.eep.uni-stuttgart.de
[3] University of Stuttgart Institute for Energy Efficiency in Production EEP, Fraunhofer Institute for Manufacturing Engineering and Automation IPA, Nobelstr. 12, D-70569 Stuttgart, +49 (0)711 970-3600, alexander.sauer@eep.uni-stuttgart.de, alexander.sauer@ipa.fraunhofer.de, www.eep.uni-stuttgart.de, www.ipa.fhg.de

Results

The results show that the daily decision model is able to support industrial companies in scheduling the EFM according to their risk appetite for the following day. It provides a compromise between a risk-taking behaviour, with high cost reduction but high risk, and risk-averse behaviour, with low risk but limited cost reduction. As an example, the results of one day are analysed. In addition, it is shown that different distribution functions have only a minor effect on decision model results. The results are given based on statistical parameters such as medium absolute error calculated over the entire year. Further improvements can be the integration of more scenarios for the prices and forecast scenarios for load and renewable generation. Moreover, the decision model can be extended to consider the bidding phase, where prices are unknown, and scheduling phase with known prices.

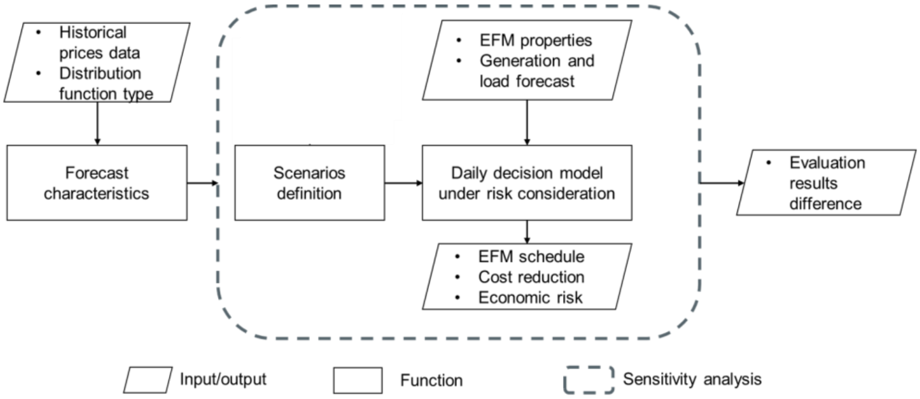

Figure 1: Method for the analysis of price distribution functions on the results of the daily decision model based on daily decision model under risk consideration.

References

[1] Bundesregierung, “Von der Kohle zur Zukunft.” [Online]. Available: https://www.bundesregierung.de/breg-de/themen/klimaschutz/kohleausstieg-1664496. (accessed on 27.11.2023).

[2] Sauer (Hrsg.), “ Energieflexibilität in der deutschen Industrie“. 2019, Stuttgart. Fraunhofer Verlag, ISBN 978-3-8396-1479-2.

[3] Fraunhofer ISI, consentec, ifeu, TU Berlin, E&R, “Langfristszenarien für die Transformation des Energiesystems in Deutschland.” 2022. [Online]. Available: https://www.langfristszenarien.de/enertile-explorer-wAssets/docs/LFS3_T45_Szenarien_15_11_2022_final.pdf (accessed on 27.11.2023).

[4] Sáez Armenteros, H. De Heer, and L. Fiorini, “Demand-side flexibility in the EU: Quantification of benefits in 2030.” smartEN, DNV, 2022. [Online]. Available: https://www.dnv.com/publications/demand-side-flexibility-quantification-of-benefits-in-the-eu-232342 (accessed on 27.11.2023).

[5] L. Bank, S. Wenninger, J. Köberlein, M. Lindner, C. Kaymakci, M. Weigold et al., “Integrating Energy Flexibility in Production Planning and Control - An Energy Flexibility Data Model-Based Approach”, 2021 CPSL Conference. DOI: https://doi.org/10.15488/11249

[6] Bianchini, K. Torolsan, and A. Sauer, “Flexibility Management for Industrial Energy Systems,” 2022. [Online]. Available: https://www.tugraz.at/fileadmin/user_upload/tugrazExternal/738639ca-39a0-4129-b0f0-38b384c12b57/files/lf/Session_C6/364_LF_Biancchini.pdf (accessed on 27.11.2023).

[7] Bianchini, L. Bitterolf, A. Sauer. „Industrial Energy Elexibility Scheduling based on Conditional Value-at-Risk”, 2023 IEEE ISGT Conference (accepted, preview)

[8] R. T. Rockafellar, S. Uryasev, “Optimization of conditional value-at-risk”. 2000, In: Journal of Risk (2), S. 21–41. DOI: 10.21314/JOR.2000.038

[9] S. Sarykalin, G. Serraino; S. Uryasev, “Value-at-Risk vs. Conditional Value-at-Risk in Risk Management and Optimization”. 2008. In: *Tutorials in Operations Research*. DOI: 10.1287/educ.1080.0052

[10] Forbes, M. Evans, N. Hastings, B. Peacock, “Statistical Distributions”. 4th Edition, 2011. John Wiley & Sons, ISBN: 978-0-470-39063-4.