GeePS Génie électrique et électronique de Paris	TotalEnergies	L2S Laboratoire Signaux & Systèmes

Decarbonization-oriented optimization of an off-grid industrial power system with renewable energy sources and battery storage

keywords

off-grid power systems, wind and solar sources, battery storage, gas turbines, power system control, real-time simulation

profile and skills of the candidate

the candidate will be graduated from a master of Science (or equivalent) in eletrical engineering

Il/elle doit avoir :

- D'excellentes connaissances en réseaux électriques, des systèmes de production d'électricité à énergies fossiles et à énergies renouvelables.
- De solides compétences en programmation.
- Une expérience sur les plateformes PHIL serait souhaitable.
- De bonnes compétences en communication orale, en lecture technique et en rédaction en anglais (des capacités en français seraient un plus).

Starting date : second quarter 2023

Résumé du projet de thèse

As the owner of a large fleet of assets requiring a large amount of electric power (in the range of 10-100 MW or more), be they located offshore (oil & gas exploration platforms) or onshore in off-grid areas, TotalEnergies has announced ambitious targets for decarbonizing these assets. In off-grid conditions (both onshore and offshore), the electricity is mainly generated by gas turbines. To reduce the CO2 emission of the latter, generators based on Renewable Energy Sources (RES), such as wind farm and solar panels, are being installed. However, a main concern with RES is the intermittency nature of their production, which will pose even more challenges for the balance between generation and demand. Often, a battery energy storage system (BESS) is needed to reach the desired level of power supply security necessary for the industrial processes. In summary, the variability and uncertainty of RES constitute a major challenge to the management of such off-grid systems with the gas turbines, RES, and storage systems (BESS).

Thus, the research topic here proposed can be summarized as the "Decarbonization-oriented optimization of an off-grid industrial power system that ensures stability and continuity of service".

The first objective is to optimize the size of the different types of energy sources and the BESS. On the demand side, based on the historical data and the long-term plan for the future, the electricity need of the site should be deduced, with details in terms of peak power, energy and variability. On the supply side, the renewable sources, in particular the wind speed and the radiation level, will be estimated based on history and similar sites. The gap between the electricity demand and the RES production will be filled by the gas turbine and the BESS, whose size should be determined as a compromise between the satisfaction of the technical specifications imposed by the sites (power quality), the decarbonization objective (CO2 emission), and the costs (CAPEX and OPEX). For this, the characteristics of the gas turbines such as minimum power, start-up time, ramping rate, minimum operation time, minimum interval between a shutdown and another startup, should be taken into account. For this step, probabilistic approaches will be explored.

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Once the size of the different types of energy sources and the BESS have been determined, their management is to be optimized. On the one hand, the production with RES should be prioritized as long as the weather conditions allow. On the other hand, the BESS should be the charged and discharged so that the gas turbines can be minimally solicited in order to reduce CO2 emission, while satisfying the constraints imposed by the loads and the features of the gas turbines. For the optimization over a time horizon, the Model Predictive Control (MPC) provides a powerful theoretical tool. The principle of "nowcast" will be adopted, where decisions will be made based on short-term forecasts. The real constraints resulting from experience feedback will be integrated, and their influences on the convergence of the algorithm and the choice of the solver will be explored. A dynamic model of the power system grid will be built, both in numerical simulation and in a real-time simulator. For the latter, an implementation with Hardware-in-the-loop (HIL) and Power Hardware-In-the-Loop (PHIL) will be considered on the platform of TotalEnergies.

Biblio :

- off-grid industrial installation
- MPC
- real time simulation of electric power system, stability issues
- probabilistic approach for power system stability surveys.

Industrial partner

The French company TotalEnergies

Academic labs

GeePs (Group of electrical engineering, Paris, https://www.geeps.centralesupelec.fr/), and L2S (https://l2s.centralesupelec.fr/)

References

[1] V Fedorenko et al 2021 IOP Conf. Ser.: Mater. Sci. Eng. 1069 012016, *A Review of Smart Off-Grid Power Systems Optimization Models for the Oil and Gas Industry* https://iopscience.iop.org/article/10.1088/1757-899X/1069/1/012016/pdf

[2] B. Boyer, « Optimisation de ressources dans un système énergétique complexe au moyen de modèles fonctionnels », thèse université Paris-Saclay, 2022

[3] H. Park, J. sun, *et al*, *Real-Time Model Predictive Control for Shipboard Power Management Using the IPA-SQP Approach*, IEEE Transactions on Control Systems Technology. Vol. : 23, Issue: 6, Nov. 2015

[4] J. Hu, Y. Shan, JM Guerrero, et al, *Model predictive control of microgrids – An overview*, Renewable and Sustainable Energy Reviews, Vol. 136, February 2021

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