Model-based predictive control of a solar reactor dedicated to syngas production

Youssef Karout, Axel Curcio, Julien Eynard, Stéphane Thil, Sylvain Rodat, Stéphane Abanades, Stéphane Grieu

To cite this version:

Youssef Karout, Axel Curcio, Julien Eynard, Stéphane Thil, Sylvain Rodat, et al.. Model-based predictive control of a solar reactor dedicated to syngas production. SOLARPACES 2022, Sep 2022, Albuquerque (Nouveau Mexique), United States. cea-04289730

HAL Id: cea-04289730
https://cea.hal.science/cea-04289730
Submitted on 16 Nov 2023

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A solar spouted-bed gasifier has been conceived by Bellouard et al. [1], and its hybrid solar-autothermal operation has been investigated by Boujjat et al. [2] and Curcio et al. [3].

This work aims at conciliating the solar-autothermal hybrid control strategy of a gasifier with the efficient implementation of a model-based predictive control (MPC) algorithm.

Goal: maintain reactor’s temperature to ensure its stability and optimal chemical reactions.

Solar reactor modeling

- Oxygen flow rate is controlled by an adaptive proportional integral derivative (PID) controller with optimized gains.
- Defocussing factor is controlled by a rule-based controller as follows:

\[
D(t) = \begin{cases} 
1, & \text{if } \text{DNI}(t) \leq 800 \text{ W m}^{-2} \text{ and } T(t) < 1473 \text{ K} \\
800 \text{ DNI}(t) & \text{if } \text{DNI}(t) > 800 \text{ W m}^{-2} \text{ and } T(t) > 1473 \text{ K}
\end{cases}
\]

Model-based predictive controller

- MPC strategy 1: maintain the reactor’s temperature at any cost.

\[
\text{minimize } \sum_{k=1}^{n} (T(t+k) - S_p)^2 \\
\text{subject to } 0 \leq D(t+k) \leq 1 \text{ and } 0 \leq f_{\text{oxygen}}(t+k) \leq 2
\]

- MPC strategy 2: maintain the reactor’s temperature, while minimizing O2 consumption and maximizing solar energy use.

\[
\text{minimize } \sum_{k=1}^{n} (T(t+k) - S_p)^2 + \beta f_{\text{oxygen}}(t+k)^2 - \gamma D(t+k)^2 \\
\text{subject to } 0 \leq D(t+k) \leq 1 \text{ and } 0 \leq f_{\text{oxygen}}(t+k) \leq 2
\]

- DNI forecasts: perfect forecasts, smart persistence forecasts, and proposed image-based forecasts.

Simulation results over one week and case studies