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Cogeneration system's energy performance improvement by using P-graph and advanced process control

Abstract

Cogeneration systems are widely used in industrial settings to meet process steam and power demands efficiently. Optimizing the load allocation among boilers and turbines is critical for improving overall system efficiency and reducing fuel consumption. However, traditional optimization approaches often rely on complex mathematical models, which can be challenging for in-house engineers without advanced optimization expertise. This study addresses this gap by utilizing a graph-theoretic tool, Process Graph (P-Graph), to optimize load allocation while considering the nonlinear part-load efficiency of boilers. Additionally, drum boilers exhibit nonlinear behaviors, such as the shrink-and-swell effect, which require advanced control strategies. To address this, various control strategies, including Proportional-Integral (PI) and Model Predictive Control (MPC), are evaluated under different high-pressure steam (HPS), medium-pressure steam (MPS), and energy demand scenarios. The study comprises two stages: optimization of load allocation among five boilers and three turbines, followed by the application of control strategies to the optimal configuration. Results show that dynamic load distribution involving Boiler 2, Boiler 3, Boiler 5, ST1, and CT achieves the best energy efficiency and cost-effectiveness. The comparison between the base and optimized scenarios underscores the changes in operating strategies achieved through optimization, resulting in a 2.38 % reduction in operating costs, equivalent to RM1727.3 per hour. Moreover, MPC outperforms PI control in closed-loop performance, demonstrating superior energy savings and error minimization.

Keywords

cogeneration; fuel consumption; P-graph; predictive controller; process network synthesis