Technical Report

Simulation and Optimization of a Regenerative Steam Power Plant

Prepared using Aspen HYSYS

Date: August 2025

1. Introduction

A regenerative steam power plant enhances the efficiency of a conventional Rankine cycle by incorporating steam extraction and reheating stages. This report outlines the steady-state process simulation of a regenerative steam cycle using Aspen HYSYS, focusing on component integration, energy recovery, and thermodynamic performance evaluation.

2. Process Description

The power plant configuration includes three steam turbines—High-Pressure (HP), Intermediate-Pressure (IP), and Low-Pressure (LP)—supported by two feedwater preheaters and two steam reheaters. High-pressure steam generated in a natural gas-fired boiler passes through the HP turbine, is reheated, and expanded successively in the IP and LP turbines.

Steam extracted from intermediate turbine stages is directed to preheat the feedwater before it enters the boiler. The boiler includes an overhead steam drum to maintain steam quality and system stability. Steam traps are employed to remove condensate and enhance heat transfer efficiency.

3. Simulation Methodology

The simulation is performed in Aspen HYSYS under steady-state conditions. Key process components are modeled with manufacturer-grade data and thermodynamic correlations. Mass and energy balances are calculated across all equipment, ensuring thermodynamic consistency throughout the plant.

The boiler uses natural gas as fuel and is modeled to generate steam at specified pressures and temperatures. The steam drum ensures separation and delivery of dry steam to the turbine stages. Each turbine stage accounts for isentropic efficiency and steam conditions. Preheaters and reheaters are modeled using energy exchangers.

4. Exergy Analysis

An exergy analysis was conducted to assess the efficiency and irreversibilities within the plant. Results indicate that turbines and heat exchangers are primary contributors to exergy destruction. This analysis provides insights into potential design improvements and process refinements aimed at reducing energy losses.

5. Energy Optimization

Based on the exergy results, several optimization strategies were evaluated. These include modifying turbine extraction pressures, optimizing reheater duty, and adjusting feedwater heater temperatures. Implementing these strategies led to an increase in overall cycle efficiency and reduced natural gas consumption.

Optimization scenarios focused on maximizing energy recovery from steam while minimizing exergy destruction and boiler load. This results in a more sustainable and cost-effective operation.

6. Conclusion

The simulation and analysis confirm that integrating reheating and feedwater preheating stages in a regenerative Rankine cycle significantly improves thermal and exergetic efficiency. The system design ensures better utilization of fuel energy and presents a strong foundation for further improvements in steam power generation.

Future work can focus on real-time process control strategies, emissions analysis, and coupling with renewable energy sources to further improve environmental performance.