INTISARI

Pembangkit Listrik Tenaga Mesin Gas (PLTMG) sering beroperasi di lokasi terpencil dengan sumber energi terbatas, memanfaatkan gas alam sebagai bahan bakar karena emisi karbonnya lebih rendah. Namun, panas buang mesin yang mencapai rata-rata 363 °C dengan laju alir massa 6,251 kg/s banyak terbuang tanpa dimanfaatkan, padahal berpotensi diubah menjadi energi tambahan melalui *Waste Heat Recovery System* (WHRS). Dua teknologi konversi panas sisa yang umum adalah *Organic Rankine Cycle* (ORC), menggunakan fluida organik yang ideal untuk suhu rendah, dan Siklus Kalina, memanfaatkan campuran amonia–air zeotropik untuk mengurangi kerugian suhu pada penukar panas. Penelitian ini bertujuan membandingkan kinerja termodinamik kedua siklus pada PLTMG 50 MW untuk menentukan metode paling efisien dan aplikatif.

Penelitian ini menggunakan pendekatan kuantitatif komparatif dengan membangun model termodinamika ORC dan Siklus Kalina di Engineering Equation Solver (EES). Tahapan dimulai dari pembuatan diagram alir penelitian, perancangan sistem ORC (pemilihan fluida kerja organik, spesifikasi operasi, skema alir) dan Siklus Kalina (spesifikasi campuran amonia–air, variasi tekanan evaporator), dilanjutkan dengan verifikasi numerik dan analisis sensitivitas untuk setiap kombinasi suhu evaporasi dan kondensasi. Media perancangan meliputi perangkat keras (laptop) dan perangkat lunak (Microsoft Word, Excel, EES), dengan asumsi steady-state dan data termofisika dari *datasheet* perusahaan serta EES. Hasil simulasi dianalisis berdasarkan neraca energi dan parameter kinerja (daya bersih, efisiensi termal, *specific work*, *back-work ratio*).

Model perancangan diverifikasi terhadap literatur dengan hasil ORC menunjukkan eror simulasi sekitar 1,36 %, sedangkan Siklus Kalina sebesar 4,7 %, menandakan keandalan model numerik . Analisis ORC pada kondisi *flue gas* masuk dan keluar sebesar 363 °C dan 70 °C yang menghasilkan daya bersih serta efisiensi termal lebih tinggi dibanding Siklus Kalina dengan *specific work* unggul dan *back-work ratio* lebih rendah. Walaupun menawarkan *specific work* kompetitif pada tekanan tinggi, Siklus Kalina memiliki kompleksitas komponen (separator, mixer) dan efisiensi yang lebih rendah pada suhu evaporasi tinggi. Perbandingan performa mengonfirmasi ORC sebagai pilihan lebih tepat untuk pemulihan panas buang PLTMG 50 MW dalam rentang kondisi operasi yang ditinjau.

Kata kunci: PLTMG 50 MW, Panas Buang, *Organic Rankine Cycle*, Siklus Kalina, Permodelan EES, Parameter Kinerja.

ABSTRACT

Gas-Turbine Power Plants often operate in remote locations with limited energy resources, using natural gas as fuel due to its lower carbon emissions. However, the exhaust heat from the turbine, averaging 363 °C with a mass flow rate of 6.251 kg/s, is largely wasted, despite its potential to be converted into additional power through a Waste Heat Recovery System (WHRS). Two common waste heat to power technologies are the Organic Rankine Cycle (ORC), which uses organic working fluids ideal for low-temperature applications, and the Kalina Cycle, which employs a zeotropic ammonia–water mixture to reduce temperature losses in the heat exchanger. This study aims to compare the thermodynamic performance of these two cycles in a 50 MW gas-turbine plant to determine the most efficient and practically applicable method.

This study employs a comparative quantitative approach by developing thermodynamic models of the ORC and the Kalina Cycle in Engineering Equation Solver (EES). The procedure begins with the preparation of the process flow diagram, followed by the design of the ORC system (selection of organic working fluid, operating specifications, flow schematic) and the Kalina Cycle (ammonia–water mixture specifications, evaporator pressure variations). Numerical verification and sensitivity analyses are then conducted for each combination of evaporation and condensation temperatures. The design tools consist of hardware (laptop) and software (Microsoft Word, Excel, and EES), under steady-state assumptions, using thermophysical data from company datasheets and EES. Simulation results are analyzed based on energy balances and performance parameters (net power output, thermal efficiency, specific work, and back-work ratio).

The design models were validated against the literature, with the ORC showing a simulation error of approximately 1.36 % and the Kalina Cycle about 4.7 %, indicating the reliability of the numerical models. Under flue-gas inlet and outlet temperatures of 363 °C and 70 °C, respectively, the ORC yielded higher net power output and thermal efficiency compared to the Kalina Cycle, along with superior specific work and a lower back-work ratio. Although the Kalina Cycle can achieve competitive specific work at elevated pressures, it involves greater component complexity (separator, mixer) and exhibits lower efficiency at high evaporation temperatures. Performance comparisons confirm the ORC as the more suitable choice for waste-heat recovery in a 50 MW gas-turbine plant within the examined operating conditions.

Keywords: 50 MW Gas-engine power plant, Waste Heat Recovery, Organic Rankine Cycle, Kalina Cycle, EES Modeling, Performance Parameters.