

ABSTRAK

Pembangkit Listrik Tenaga Diesel (PLTD) masih menjadi tulang punggung penyediaan energi listrik di wilayah kepulauan dan sistem terisolasi di Indonesia, namun memiliki kelemahan utama berupa konsumsi bahan bakar yang tinggi, biaya operasi besar, serta emisi gas rumah kaca yang signifikan. Penelitian ini bertujuan untuk menganalisis kinerja teknis, ekonomi, keandalan, dampak lingkungan serta kontribusi kebijakan dedieselisasi dari pengembangan sistem PLTD hibrida berbasis Pembangkit Listrik Tenaga Surya (PLTS) dan *Battery Energy Storage System* (BESS). Metode penelitian menggunakan pendekatan kuantitatif berbasis simulasi dengan perangkat lunak HOMER, dengan membandingkan tiga skenario sistem, yaitu PLTD murni, PLTD–PLTS, dan PLTD–PLTS–BESS. Analisis dilakukan terhadap kinerja energi, konsumsi bahan bakar dan *Specific Fuel Consumption* (SFC), parameter ekonomi (*Net Present Cost*, *Operating Cost*, *Levelized Cost of Energy*, dan *Payback Periode*), keandalan sistem (*excess electricity*, *unmet load*, dan *capacity shortage*), serta emisi karbon dioksida (CO₂).

Hasil simulasi operasi tahunan menunjukkan bahwa integrasi PLTS 1 MWp dan BESS 1 MWh pada PLTD 6 MW mampu meningkatkan kinerja sistem secara signifikan. Sistem PLTD–PLTS–BESS menghasilkan penurunan SFC sebesar 4,70%, serta penurunan emisi CO₂ sebesar 4,41% dibandingkan PLTD murni dalam perhitungan satu tahun operasi. Dari sisi ekonomi, nilai *Net Present Cost* (NPC) menurun sebesar 3,31% selama 20 tahun umur proyek, *Operating Cost* tahunan turun 4,78%, dan LCOE menurun sebesar 3,58% menjadi 0,2234 USD/kWh, dengan *Payback Period* sebesar 2,91 tahun. Selain itu, keandalan sistem meningkat dengan penurunan *unmet load* dan *capacity shortage* secara signifikan. Berdasarkan hasil tersebut, dapat disimpulkan bahwa sistem PLTD–PLTS–BESS merupakan konfigurasi yang paling optimal dan berkelanjutan untuk sistem kelistrikan berbasis PLTD di wilayah kepulauan Indonesia.

Kata kunci: PLTD, PLTS, BESS, Sistem Hibrida, HOMER, SFC, NPC, *Operating Cost*, LCOE, *Payback Periode*, Keandalan, Emisi CO₂

ABSTRACT

Diesel Power Plants (PLTD) remain the backbone of electricity supply in archipelagic regions and isolated systems in Indonesia. However, they have major drawbacks, including high fuel consumption, large operating costs, and significant greenhouse gas emissions. This study aims to analyze the technical performance, economic performance, reliability, environmental impact, and the contribution to the diesel-reduction (dedieselization) policy from the development of a hybrid PLTD system based on Solar Power Plants (PLTS) and a Battery Energy Storage System (BESS). The research method uses a quantitative simulation-based approach employing HOMER software by comparing three system scenarios: pure PLTD, PLTD–PLTS, and PLTD–PLTS–BESS. The analysis evaluates energy performance, fuel consumption and Specific Fuel Consumption (SFC), economic parameters (Net Present Cost, Operating Cost, Levelized Cost of Energy, and Payback Period), system reliability (excess electricity, unmet load, and capacity shortage), and carbon dioxide (CO₂) emissions.

Annual operational simulation results indicate that the integration of 1 MWp PV (PLTS) and 1 MWh BESS into a 6 MW diesel power plant (PLTD) significantly improves overall system performance. The PLTD–PLTS–BESS configuration achieves a 4.70% reduction in Specific Fuel Consumption (SFC) and a 4.41% reduction in CO₂ emissions compared to the diesel-only system, based on one year of operation. From an economic perspective, the Net Present Cost (NPC) decreases by 3.31% over the 20-year project lifetime, while the annual operating cost is reduced by 4.78%, and the Levelized Cost of Energy (LCOE) decreases by 3.58% to 0.2234 USD/kWh, with a payback period of 2.91 years. In addition, system reliability improves significantly, as indicated by reductions in unmet load and capacity shortage. Based on these results, it can be concluded that the PLTD–PLTS–BESS configuration represents the most optimal and sustainable solution for diesel-based power systems in Indonesia's island regions.

Keywords: PLTD, PLTS, BESS, Hybrid System, HOMER, SFC, NPC, Operating Cost, LCOE, Payback Period, Reliability, CO₂ Emissions