ABSTRAK

Eben Ronitua Sitompul. Analisa Keekonomian dan Optimalisasi Pemodelan Sistem Pembangkit Microgrid Untuk Mendukung Dedieselisasi di Pulau Bunaken, Sulawesi Utara. Dibimbing oleh Dr. Tri Wahyu Adi, SE., MM., CRGP.

Sistem kelistrikan Pulau Bunaken telah bertransformasi menjadi sistem hibrida PLTD–PLTS–BESS, namun masih menghadapi biaya penyediaan listrik yang tinggi, ketergantungan terhadap bahan bakar minyak, serta pemanfaatan energi terbarukan yang belum optimal. Penelitian ini bertujuan menganalisis keekonomian dan mengoptimalkan pemodelan sistem *microgrid* eksisting untuk mendukung program dedieselisasi di Pulau Bunaken. Penelitian menggunakan pendekatan *mixed-method* sekuensial eksplanatori yang mengintegrasikan simulasi dan optimasi tekno-ekonomi menggunakan HOMER Pro dengan analisis jalur menggunakan *Partial Least Squares–Structural Equation Modeling* (PLS-SEM). Empat skenario dianalisis, yaitu kondisi *baseline*, optimalisasi strategi operasi, revitalisasi sistem PLTS, dan dedieselisasi 100% berbasis energi terbarukan. Hasil penelitian menunjukkan bahwa energi surya merupakan sumber energi terbarukan yang paling layak dikembangkan di Pulau Bunaken, sedangkan energi angin, arus laut, dan biomassa memiliki keterbatasan teknis maupun lingkungan. Simulasi menunjukkan bahwa optimalisasi aset eksisting dan revitalisasi PLTS merupakan tahapan strategis untuk meningkatkan kinerja sistem dan menekan biaya sebelum menuju dedieselisasi penuh. Skenario 100% energi terbarukan secara teknis dapat diterapkan, namun kelayakan ekonominya sangat dipengaruhi oleh harga BBM, kebutuhan investasi, dan modernisasi sistem penyimpanan energi. Analisis PLS-SEM menunjukkan bahwa keekonomian, desain dan kinerja teknis, serta faktor lingkungan dan sosial memiliki keterkaitan yang signifikan dalam pembentukan model optimalisasi, dengan keekonomian memberikan pengaruh langsung terbesar terhadap optimalisasi, sedangkan desain dan kinerja teknis berperan penting melalui keterkaitannya dengan keekonomian. Berdasarkan integrasi kedua pendekatan tersebut, penelitian merekomendasikan strategi dedieselisasi bertahap melalui prinsip *optimize–modernize–decarbonize*, yaitu optimalisasi aset eksisting, modernisasi PLTS dan BESS, serta transisi menuju sistem energi terbarukan secara penuh. Pendekatan *brownfield optimization* yang terintegrasi dengan PLS-SEM menjadi kontribusi penelitian dalam mendukung pengambilan keputusan dedieselisasi pada sistem kelistrikan pulau kecil dan kawasan konservasi.

Kata kunci: *microgrid*, *brownfield optimization*, dedieselisasi, HOMER Pro, PLS-SEM, Pulau Bunaken.

ABSTRACT

Eben Ronitua Sitompul. *Economic Analysis and Optimization of Microgrid Generation System Modeling to Support Dedieselization on Bunaken Island, North Sulawesi.* Supervised by Dr. Tri Wahyu Adi, S.E., M.M., CRGP.

The electricity system of Bunaken Island has transitioned into a hybrid diesel–PV–BESS system; however, it continues to face high electricity supply costs, dependence on diesel fuel, and suboptimal utilization of renewable energy. This study aims to analyze the economic performance and optimize the existing microgrid system model to support the dedieselization program on Bunaken Island. A sequential explanatory mixed-method approach was employed by integrating techno-economic simulation and optimization using HOMER Pro with path analysis using Partial Least Squares–Structural Equation Modeling (PLS-SEM). Four scenarios were evaluated, comprising the baseline condition, operational strategy optimization, PV system revitalization, and 100% renewable-energy-based dedieselization. The results indicate that solar energy is the most feasible renewable energy resource for further development on Bunaken Island, whereas wind, marine current, and biomass resources are constrained by technical and environmental limitations. The simulations demonstrate that optimizing existing assets and revitalizing the PV system represent strategic stages for improving system performance and reducing costs prior to full dedieselization. A 100% renewable energy system is technically feasible; however, its economic viability is strongly influenced by diesel fuel prices, investment requirements, and modernization of the energy storage system. The PLS-SEM analysis indicates significant interrelationships among economic viability, technical performance, and environmental and social factors in shaping the optimization model. Economic viability provides the strongest direct influence on optimization, while technical performance plays an important role through its relationship with economic viability. Based on the integration of both analytical approaches, this study recommends a phased dedieselization strategy based on the optimize–modernize–decarbonize principle, consisting of optimization of existing assets, modernization of the PV and BESS systems, and transition toward a fully renewable energy system. The integration of brownfield optimization and PLS-SEM represents the main contribution of this study to supporting dedieselization decision-making for small-island power systems and conservation areas.

Keywords: *microgrid, brownfield optimization, dedieselization, HOMER Pro, PLS-SEM, Bunaken Island.*