INTISARI

Konsumsi bahan bakar gas alam pada Pembangkit Listrik Tenaga Gas (PLTG) Gas Turbin Generator di fasilitas *Floating Production Unit* (FPU) Jangkrik menjadi salah satu tantangan utama dalam upaya efisiensi energi sektor migas lepas pantai. PLTG berperan penting dalam menunjang proses produksi gas alam, namun konsumsi bahan bakar gas (BBG) mencapai sekitar 4% dari total produksi gas, dengan rerata penggunaan sebesar 65,9 MMSCF per bulan atau senilai Rp 2,3 miliar per bulan. Nilai ini menunjukkan beban biaya operasional yang signifikan, sekaligus ketergantungan yang tinggi terhadap energi fosil. Oleh karena itu, diperlukan upaya optimasi untuk menekan konsumsi BBG dan biaya operasional, serta mendukung transisi menuju sistem energi yang lebih berkelanjutan. Penelitian ini dilaksanakan pada Unit Produksi Terapung (FPU) di lepas pantai Selat Makassar, sekitar 70 km dari garis pantai Kalimantan Timur.

Sebagai solusi atas permasalahan tersebut, penelitian ini mengusulkan rancangan sistem pembangkit listrik hibrida yang mengintegrasikan PLTG dengan Pembangkit Listrik Tenaga Surya (PLTS) solar photovoltaic (PV) untuk memenuhi kebutuhan energi di area Living Quarter (LQ). Tujuannya adalah mengurangi konsumsi bahan bakar gas alam dan emisi karbon melalui pemanfaatan energi surya yang melimpah. Pendekatan yang digunakan meliputi perancangan dan pemodelan sistem PLTS–PLTG hibrida pada jaringan kelistrikan FPU, simulasi kinerja sistem terhadap kestabilan tegangan dan efisiensi distribusi daya, analisis kontribusi PLTS terhadap pengurangan konsumsi bahan bakar fosil dan emisi gas rumah kaca (GRK), serta evaluasi keekonomian proyek melalui metode Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), dan Net Benefit Cost Ratio (Net B/C).

Rancangan sistem PLTS yang dikembangkan terdiri atas 75 modul surya dengan konfigurasi 5 string, disesuaikan dengan keterbatasan lahan di area offshore seluas 15 × 15 m². Hasil desain menghasilkan kapasitas daya sebesar 35,5 kW. Simulasi sistem menunjukkan kinerja yang stabil dan andal, dengan tegangan bus tetap pada 0,4 kV dan efisiensi tegangan berkisar antara 99,02% hingga 99,19%. Integrasi PLTS dengan sistem PLTG terbukti mampu menjaga kontinuitas pasokan listrik di area Living Quarter tanpa menurunkan keandalan pada sistem kelistrikan yang sudah ada.

Hasil penelitian menunjukkan bahwa penerapan sistem PLTS–PLTG hibrida mampu menurunkan konsumsi bahan bakar gas sebesar 5.318,88 MMBTU per tahun, yang ekuivalen dengan penghematan biaya operasional PLTG sebesar Rp 327.643.008 per tahun. Selain manfaat ekonomi, sistem ini juga berkontribusi terhadap aspek lingkungan melalui penurunan emisi GRK sebesar 323,75 ton CO_2eq per tahun. Capaian ini sejalan dengan target Enhanced Nationally Determined Contribution (ENDC) Indonesia, yaitu pengurangan emisi sebesar 32% atau setara 915 juta ton CO_2 pada tahun 2030. Berdasarkan hasil analisis keekonomian, proyek PLTS hibrida berkapasitas 35,5 kW dinyatakan layak diimplementasikan dengan nilai NPV sebesar Rp 1 miliar, IRR mencapai 30,5% melampaui suku bunga acuan nasional 5,5%, PP selama 4 tahun, dan rasio Net B/C sebesar 4,1.

Kata Kunci: Energi Terbarukan, PLTS, PLTG, Sistem Hibrida, Keekonomian Energi, Penurunan Emisi GRK.

ABSTRACT

The consumption of natural gas fuel in the Gas Turbine Generator (GTG) Power Plant at the Floating Production Unit (FPU) Jangkrik facility represents one of the main challenges in improving energy efficiency in the offshore oil and gas sector. The GTG plays a crucial role in supporting the natural gas production process. however, its fuel gas consumption accounts for approximately 4% of total gas production, with an average usage of 65.9 MMSCF per month or equivalent to IDR 2.3 billion per month. This figure indicates a significant operational cost burden as well as a high dependency on fossil-based energy. Therefore, optimization efforts are required to reduce both gas fuel consumption and operating costs while supporting the transition toward a more sustainable energy system. This study was conducted on an offshore Floating Production Unit (FPU) located in the Makassar Strait, approximately 70 km from the coastline of East Kalimantan.

As a solution to the mentioned problem, this research proposes the design of a hybrid power generation system that integrates a Gas Turbine Generator (GTG) with a Solar Photovoltaic (PV) to meet energy demands in the Living Quarter (LQ) area. The objective is to reduce natural gas fuel consumption and carbon emissions through the utilization of abundant solar energy. The adopted approach includes designing and modeling the PLTS–PLTG hybrid system within the FPU's electrical network, simulating system performance in terms of voltage stability and power distribution efficiency, analyzing the PLTS contribution to reducing fossil fuel consumption and greenhouse gas (GHG) emissions, as well as assessing the project's economic feasibility through Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), and Net Benefit-Cost Ratio (Net B/C) analyses.

The proposed PLTS system consists of 75 solar modules arranged in 5 strings, optimized according to the limited offshore installation area of 15 × 15 m². The design results indicate a total power capacity of 35.5 kW. Simulation results demonstrate stable and reliable hybrid system performance, maintaining the bus voltage at 0.4 kV with a voltage efficiency ranging from 99.02% to 99.19%. The integration of solar PV into the existing GTG system has proven capable of maintaining continuous power supply for the Living Quarter area without compromising the reliability of the existing electrical network.

The results of this study show that the implementation of the PLTS–PLTG hybrid system can reduce gas fuel consumption by 5,318.88 MMBTU per year, equivalent to an operational cost saving of IDR 327,643,008 per year for the gas turbine generator. In addition to economic benefits, the system also contributes to environmental improvement by reducing greenhouse gas emissions by 323.75 tons of CO_2eq per year. This achievement aligns with Indonesia's Enhanced Nationally Determined Contribution (ENDC) target of a 32% emission reduction, equivalent to 915 million tons of CO_2 by 2030. Based on the economic feasibility analysis, the 35.5 kW PLTS hybrid project is declared feasible for implementation, with an NPV of IDR 1 billion, an IRR of 30.5% (significantly exceeding the national reference interest rate of 5.5%), a payback period of 4 years, and a Net B/C ratio of 4.1.

Keywords: Renewable Energy, PLTS, PLTG, Hybrid System, Energy Economics, GHG Emission Reduction.