ANALISIS PEMANFAATAN PLTS *ON-GRID* DENGAN *BACKUP BATTERY ENERGY STORAGE SYSTEM (BESS)* UNTUK *BACKUP* DAN *PEAK SHAVING* PADA *EV CHARGING STATION* DI REST AREA JALAN TOL KM 57 DAN KM 164 B

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ABSTRAK

Peningkatan penggunaan kendaraan listrik mendorong kebutuhan infrastruktur Stasiun Pengisian Kendaraan Listrik Umum (SPKLU) yang andal dan berkelanjutan. Penelitian ini menganalisis pemanfaatan Pembangkit Listrik Tenaga Surya (PLTS) *on-grid* yang terintegrasi dengan *Battery Energy Storage System* (BESS) untuk fungsi *backup* dan *peak shaving* pada SPKLU *Rest Area* KM 57 Jalan Tol Jakarta-Cikampek dan KM 164 B Jalan Tol Cikopo-Palimanan. Metode penelitian menggunakan pendekatan kuantitatif-deskriptif melalui analisis spasial menggunakan ArcGIS Pro, pengolahan potensi energi surya dari Global Solar Atlas, analisis karakteristik *charger* dan kebutuhan energi SPKLU, *demand-based sizing* PLTS, penerapan *safety factor* jumlah modul, perancangan BESS, skema operasi *zero export*, serta analisis ekonomi menggunakan *Net Present Value* (NPV), *Internal Rate of Return* (IRR), *Payback Period*, dan *Levelized Cost of Energy* (LCOE).

Kebutuhan energi tahunan SPKLU diperoleh sebesar 84.279 kWh pada KM 57 dan 37.979 kWh pada KM 164 B. Kapasitas minimum PLTS adalah 58,30 kWp atau 106 modul pada KM 57 dan 25,85 kWp atau 47 modul pada KM 164 B. Analisis sensitivitas *safety factor* 1,1; 1,2; dan 1,5 menunjukkan bahwa peningkatan *safety factor* meningkatkan kapasitas dan CAPEX, tetapi menurunkan kelayakan ekonomi karena tambahan produksi tidak seluruhnya dapat dimonetisasi pada sistem *zero export*. Dari ketiga skenario, *safety factor* 1,1 memberikan *trade-off* terbaik dan menghasilkan konfigurasi desain 64,35 kWp atau 117 modul pada KM 57 serta 28,60 kWp atau 52 modul pada KM 164 B. BESS tetap dirancang sebesar 500 kW/700 kWh pada KM 57 dan 60 kW/100 kWh pada KM 164 B untuk mendukung *backup* sekitar satu jam dan *peak shaving*. Hasil sensitivitas menunjukkan bahwa pada *safety factor* 1,1, NPV PLTS menjadi sekitar -Rp26,48 juta dengan IRR 9,50%, *Payback Period* sekitar 9,3 tahun dan LCOE Rp1.496,00/kWh pada KM 57, sedangkan KM 164 B menghasilkan NPV sekitar -Rp7,15 juta, IRR 9,70%, *Payback Period* sekitar 9,1 tahun dan LCOE Rp1.475,45/kWh. Dengan demikian, safety factor 1,1 direkomendasikan sebagai margin desain yang paling rasional di antara skenario yang diuji, sedangkan implementasi BESS tetap lebih tepat dinilai berdasarkan nilai keandalan, *backup*, dan *peak shaving* daripada penghematan energi semata.

Kata kunci: PLTS *on-grid*, BESS, SPKLU, *peak shaving*, *backup*, *safety factor*, *zero export*, LCOE.

ANALYSIS OF ON-GRID PHOTOVOLTAIC SYSTEM UTILIZATION WITH BATTERY ENERGY STORAGE SYSTEM (BESS) FOR BACKUP AND PEAK SHAVING AT ELECTRIC VEHICLE CHARGING STATIONS IN KM 57 AND KM 164 B TOLL ROAD REST AREAS

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ABSTRACT

The increasing adoption of electric vehicles drives the need for reliable and sustainable Public Electric Vehicle Charging Station (EVCS) infrastructure. This study analyzes the utilization of an on-grid photovoltaic (PV) system integrated with a Battery Energy Storage System (BESS) for backup and peak-shaving functions at the KM57 Jakarta-Cikampek Toll Road Rest Area and the KM164B Cikopo-Palimanan Toll Road Rest Area. A quantitative-descriptive approach was applied through spatial analysis using ArcGIS Pro, solar resource assessment using Global Solar Atlas, analysis of charger characteristics and EVCS energy demand, demand-based PV sizing, module safety-factor scenarios, BESS sizing, zero-export operation, and economic evaluation using Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period, and Levelized Cost of Energy (LCOE).

Annual EVCS energy demand is 84,279 kWh at KM57 and 37,979 kWh at KM164B. The minimum PV capacities are 58.30 kWp (106 modules) and 25.85 kWp (47 modules), respectively. Sensitivity analysis using module safety factors of 1.1, 1.2, and 1.5 shows that higher safety factors increase installed capacity and CAPEX but reduce economic feasibility because additional generation cannot be fully monetized under a zero-export scheme. Among the evaluated scenarios, a safety factor of 1.1 provides the best technical-economic trade-off, resulting in 64.35 kWp (117 modules) at KM57 and 28.60 kWp (52 modules) at KM164B. The BESS remains sized at 500 kW/700 kWh for KM57 and 60 kW/100 kWh for KM164B to support approximately one hour of backup and peak shaving. Under the 1.1 safety-factor scenario, KM57 yields an NPV of approximately -IDR 26.48 million, an IRR of 9.50%, a Payback Period of approximately 9.3 years, and an LCOE of IDR 1,496.00/kWh. KM164B yields an NPV of approximately -IDR 7.15 million, an IRR of 9.70%, a Payback Period of approximately 9.1 years, and an LCOE of IDR 1,475.45/kWh. Therefore, a safety factor of 1.1 is recommended as the most rational design margin among the tested scenarios, while BESS implementation should primarily be justified by reliability, backup, and peak-shaving value rather than energy-cost savings alone.

Keywords: *on-grid PV, BESS, EVCS, peak shaving, backup, safety factor, zero export, LCOE.*