OPTIMALISASI *MAXIMUM POWER POINT TRACKING* DENGAN ALGORITMA HIBRIDA DAN KONTROL ADAPTIF UNTUK MENURUNKAN *RIPPLE* DAYA PADA PANEL SURYA

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ABSTRAK

Peningkatan pemanfaatan panel surya memerlukan *Maximum Power Point Tracking* (MPPT) yang mampu menjaga panel surya beroperasi di sekitar titik daya maksimum. Algoritma *Perturb and Observe* (P&O) dan *Incremental Conductance* (INC) banyak digunakan karena sederhana, tetapi masih menghasilkan *ripple* daya *steady state* dan respons transien yang belum optimal. Penelitian ini bertujuan untuk merancang algoritma MPPT hibrida dengan kontrol adaptif untuk menurunkan *ripple* daya pada sistem panel surya berbasis *boost converter*. Algoritma hibrida menggabungkan arah koreksi P&O, indikator kedekatan MPP berbasis INC, *adaptive step*, *hysteresis*, *dwell time*, dan *holding strategy*. Pengujian dilakukan melalui simulasi pada iradiasi 1000 W/m² dan 750 W/m², dengan P&O dan INC sebagai pembanding. Hasil simulasi menunjukkan algoritma hibrida mempertahankan rata - rata daya *output steady state* sebesar 2.558 kW terhadap daya teoritis 2.563 kW dan 1.931 kW terhadap 1.940 kW. *Ripple* daya turun hingga 9×10^{-9} kW dan 5×10^{-9} kW pada rentang yang digunakan, dengan *settling time* tercepat 0.032 s dan 0.036 s dengan *trade off* dimana daya rata - rata *steady state* T1 sedikit lebih rendah karena algoritma hibrida membatasi perubahan *duty* ketika sistem dekat MPP. Namun, selisihnya kecil dan diimbangi *ripple* yang jauh lebih rendah dan respons pelacakan yang lebih cepat.

Kata kunci: Algoritma Hibrida, *Maximum Power Point Tracking* (MPPT), *Ripple* daya, Panel surya.

OPTIMIZATION OF MAXIMUM POWER POINT TRACKING WITH HYBRID ALGORITHM AND ADAPTIVE CONTROL TO MINIMIZE RIPPLE POWER ON SOLAR PANEL

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ABSTRACT

Solar panel utilization requires a Maximum Power Point Tracking (MPPT) system capable of maintaining photovoltaic operation near the Maximum Power Point. Perturb and Observe (P&O) and Incremental Conductance (INC) are widely used due to their simplicity and effectiveness; however they still produce steady state power ripple and suboptimal transient response. This study designs a hybrid MPPT algorithm with adaptive control to reduce power ripple in a photovoltaic system using a boost converter. The proposed algorithm combines the P&O correction direction, an INC based MPP proximity indicator, adaptive step, hysteresis, dwell time, and holding strategy. Simulations were conducted under irradiance levels of 1000 W/m² and 750 W/m², using P&O and INC as baselines. The hybrid algorithm maintained steady-state average output power of 2.558 kW against 2.563 kW and 1.931 kW against 1.940 kW. The hybrid power ripple decreased to 9×10^{-9} kW and 5×10^{-9} kW in range used. It also achieved the fastest settling time of 0.032 s and 0.036 s. Although its average power in T1 was slightly lower, the difference was small and remained close to the theoretical value. Therefore, the hybrid algorithm reduces ripple, accelerates tracking toward the MPP, and improves power stability.

Keywords: *Hybrid Algorithm*, *Maximum Power Point Tracking* (MPPT), *Ripple power, Settling time.*