

INTISARI

Penggunaan *photovoltaic* (PV) terus meningkat seiring kebutuhan listrik global, tetapi efisiensi kelistrikannya rentan menurun secara signifikan akibat peningkatan temperatur saat terpapar radiasi matahari. Terutama di kawasan iklim tropis, penerapan sistem manajemen termal (TMS) aktif seperti *liquid channel cooling* yang dipadukan dengan *solar tracking system* sangat relevan untuk mencegah degradasi efisiensi tersebut. Penelitian ini bertujuan untuk menginvestigasi efektivitas penggunaan TMS secara eksperimental dalam meredam suhu berlebih panel PV agar beroperasi pada titik optimal dan memaksimalkan *net-power generation* secara keseluruhan.

Penelitian ini menginvestigasi secara eksperimental kinerja TMS berbasis *liquid channel* berbentuk *serpentine* pada panel PV 100 Wp yang terintegrasi dengan *dual-axis solar tracker* di Fakultas Teknik, Universitas Gadjah Mada. Pengujian dilakukan pada kondisi lingkungan aktual dengan memvariasikan laju aliran fluida air. Pengujian berfokus mengevaluasi performa PV dalam dua kondisi, yaitu modul konvensional tanpa TMS dan modul bermanajemen termal dengan variasi laju aliran sebesar 1,5 LPM, 2 LPM, 2,5 LPM, 3 LPM, hingga 3,5 LPM. Parameter pengamatan meliputi laju kalor yang diserap, *heat transfer coefficient*, *pressure drop*, efisiensi elektrik panel, serta *cooling performance index* pompa yang digunakan.

Hasil pengujian menunjukkan intervensi TMS sukses menjaga suhu operasi panel di kisaran 35°C–43°C, meredam panas berlebih dibandingkan kondisi konvensional (56,5°C). Peningkatan laju aliran secara signifikan menaikkan koefisien perpindahan kalor hingga mencapai 1621,76 W/m².K, meredam suhu hingga rata-rata 38°C, serta meningkatkan efisiensi listrik menembus 16,7% pada 3,5 LPM. Walaupun 3,5 LPM memberikan pendinginan paling maksimal, evaluasi timbal balik operasional menyimpulkan bahwa 1,5 LPM adalah setup paling optimal. Laju aliran 1,5 LPM mampu menyeimbangkan stabilitas daya panel dengan konsumsi daya pompa yang efisien sebesar 7,2 W, sehingga menghasilkan *cooling performance index* tertinggi sebesar 25,74.

Kata kunci: *photovoltaic* (PV), sistem manajemen termal, *liquid channel*, efisiensi PV, laju aliran fluida

ABSTRACT

As global electricity demand rises, the deployment of photovoltaic (PV) systems continues to expand. However, their electrical efficiency is highly vulnerable to degradation caused by elevated operating temperatures under solar radiation. Particularly in tropical climates, integrating active thermal management systems (TMS), such as liquid channel cooling, with solar tracking mechanisms is important to prevent this performance loss. This study experimentally investigates the effectiveness of a TMS in mitigating excessive PV temperatures, thereby ensuring optimal operation and maximizing overall net power generation.

The experiment evaluated a serpentine liquid channel TMS attached to a 100 Wp PV panel integrated with a dual-axis solar tracker. Experiment conducted under actual environmental conditions at the Faculty of Engineering, Universitas Gadjah Mada. The study focused on compared a conventional uncooled PV module against a thermally managed one. Water was utilized as the cooling fluid, with flow rates varied at 1.5, 2.0, 2.5, 3.0, and 3.5 liters per minute (LPM). Key performance parameters measured included the absorbed heat rate, heat transfer coefficient, pressure drop, electrical efficiency, coefficient of power efficiency, and cooling performance index.

The experimental results indicate that the TMS intervention successfully maintained the panel's operating temperature within the range of 35°C–43°C, effectively mitigating excessive heat compared to the conventional condition (56.5°C). Increasing the flow rate significantly enhanced the heat transfer coefficient up to 1621.76 W/m².K, reduced the temperature to an average of 38°C, and increased the electrical efficiency to reach 16.7% at 3.5 LPM. Although the 3.5 LPM flow rate provided the maximum cooling effect, the operational trade-off evaluation concluded that 1.5 LPM is the most optimal setup. The 1.5 LPM flow rate is capable of balancing the stability of the panel's power output with an efficient pump power consumption of 7.2 W, thereby yielding the highest cooling performance index of 25.74.

Keywords: photovoltaic (PV), thermal management system, liquid channel, PV efficiency, flow rate