Experimental Performance of a Seasonally Adaptive Asymmetric Compound Parabolic Concentrator

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ABSTRACT

While tracking solar concentrators are a useful technology for high temperature applications including concentrating solar power (CSP), their tracking systems make them complex and expensive when implemented for lower temperature applications, including process and space heating. By removing the need for tracking, stationary solar concentrators are a promising low-cost technology to meet the demand for such low to medium temperature applications. The implementation of stationary concentrators at high latitudes, where acceptance angles are not symmetrical, favours the use of Asymmetric Compound Parabolic Concentrators (ACPCs). But, when year-round concentration is desired, stationary concentrators face a difficult challenge due to the inverse relationship between the maximum geometric concentration ($C_{g,max}$) and the acceptance angle. To address this, we developed an innovative reconfigurable stationary ACPC. The design features two configurations, one for winter and one for summer, which are interchanged by a simple switching movement of one of the mirror walls. This reconfigurable ACPC allows for year-round performance with a concentration surpassing the theoretical limit for a standard non-reconfigurable design. A prototype was developed for Toronto’s latitude (43.7° North) and was designed to have at least 6 hours of useful collection time year-round. The resulting design has an acceptance half-angle of $\theta_i = 45^\circ$, and can reach average concentrations of up to 2×, which notably surpasses the theoretical maximum concentration of $C_{g,max,2D} = 1/\sin\theta_i =1.41\times$. The prototype design was evaluated using both Monte Carlo Ray Tracing (MCRT) simulations and outdoor flux mapping experiments. The MCRT simulations have been found to line up well with both theory and experimental results. The outdoor experiments were performed at the rooftop of the Bergeron Center in York University, Toronto (43.772° North, 79.507° West) utilizing an innovative flux-mapping procedure. Experiments were performed near Summer Solstice, September Equinox and Winter Solstice, demonstrating good real-world performance at different solar altitudes. The results obtained show that the reconfigurable ACPC is a low-cost alternative to meet low to medium temperature heating demands sustainably at high latitudes.