Proceedings of the 6th International Conference on Energy Harvesting, Storage, and Transfer (EHST'22)
Niagara Falls, Canada - June 08-10, 2022
Paper No. 117
DOI: 10.11159.ehst22.117

Maximizing Performance of Ground-Coupled Heat Exchanger under Hot-Wet Climate Condition: Experimental and Numerical Analysis

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Extended Abstract

Both experimental and numerical studies are conducted to investigate the performance, efficacy and feasibility of ground coupled heat exchanger (GCHE) as a sustainable heat rejection method that will reduce power consumption in A/C systems employed in hot and humid climates. Following the numerical analysis by Kahwaji et al. 2021 [1] to optimize the design of GCHE, a setup has been established made of coaxial tube configuration with insulated inner pipe. Five boreholes (four load-connected and one unloaded) are drilled with 40 m depth and 0.09 m outside diameter. The loaded boreholes are positioned on the corners of an 8x8 m square and the unloaded borehole in the centre. The unloaded hole is used for sensing ground temperature. The system is fabricated from HDPE outside and PVC inside pipes to combat corrosion from salty ground water and reduce cost. Water-cooled A/C system is selected and connected to the GCHE to provide a practical cooling load (8 kW of condenser heat rejection). A regular air-cooled A/C system with the same cooling load is installed for comparison. The time-dependent water-side pressure, temperature, flowrate as well as power consumptions are measured. To cover the required span of parameters, the experimental process utilizes different coolant flowrates, heat exchangers connection configurations (parallel, series, mix parallel + series), and borehole rotations (three boreholes working with one stand by at different time intervals). For validation and to deeply investigate the overall performance of the GCHE and performing its design optimization, a computational fluid dynamics (CFD) model using ANSYS FLUENT is developed [1]. The model is to simulate water flow in two concentric tubes connected together (simulating the coaxial type of the heat exchanger) and buried in a ground material simulating the soil region. The measurements and numerical results are in a good agreement within an average and maximum estimated error of 1.55% and 5.19% respectively. The results showed that the heat rejection capacity correlates well with the flow and the heat exchanger was able to maintain the coolant temperature drop at the design 5 °C at design loads and an average of 4.4 °C when the load exceeded the design. The measured heat rejection capacity of the installed heat exchanger was at 83.7% of the design capacity due to higher local ground temperature than that assumed in the simulation and much lower ground porosity. The results also showed that the GCHE system is effective in saving energy with a maximum recorded energy saving of ~20% at high ambient temperature periods and an average of 7-12% during day time periods. The system is perfectly suited to office applications where the load is mainly during the day. Full day, 24-hour, operations showed that the system cumulative energy savings is small and depends on night time ambient temperatures.

References

[1] G. Y. Kahwaji, D. Capuano, G. Boudekji, M. A. Samaha, “Optimization of high-capacity ground-coupled heat exchanger under hot-wet climate condition: numerical approach,” in *Proceedings of the 6th International Conference on Energy Harvesting, Storage, and Transfer (EHST'22)*, Niagara Falls, Canada, June 08–10, 2022.