



Electricity production by solar thermo-hydraulic engine for residential use

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An original way to convert heat into work by implementing a solar thermo-hydraulic engine has been developed. The thermodynamical cycle is similar to the Rankine's one but the work is produced by an hydraulic turbine (or motor) instead of a classical steam turbine. This novel process is capable to reach a high exergetic efficiency of 60%. Thermal solar collectors ensure the need for heating and hot domestic water, whereas the thermo-hydraulic engine enables electricity production all year long, especially in summer. A first study have showed the feasibility of this thermo-hydraulic engine on a small-scale pilot (100 W) using a hydraulic motor. These experiments showed a lack of performance mainly due to the energy conversion chain, hydraulic/mechanical/electric, that was about only 40% efficient. Nevertheless simulations carried out with a Francis-type turbine as hydraulic/mechanical converter have led to better performances.

In this paper, a quasi-static study of the process is carried out in order to define the best operating conditions, such as the mass flow rates and the operating pressures of the cycle. A parametric study is performed to determine the optimal driving temperature of the process, that maximizes the global solar efficiency and thus, leads to a minimal solar collectors area for a given electric power. As a matter of fact, the efficiency of the thermo-hydraulic engine increases with this temperature while solar collectors efficiency decreases. These results will also enable the choice of the best suitable working fluid for electricity production, especially with low GWP such as the HFO-1233zd. The results of parametric study also help in designing the hydraulic Francis-type turbine that is required for a future small-scale pilot of 1kW. One challenging point of this study is to develop a turbine that can operate dynamically with operating pressures varying over a wide range, all the while achieving a high efficiency. Finally, performance comparison and discussion with other similar current systems like organic Rankine cycles or the Stirling cycles will be performed.

Keywords: Low-temperature thermal solar conversion; Thermo-hydraulic cycle; Francis turbine; dynamic modeling