Simulation Study of an Innovative Solar Absorption Refrigeration System

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Författare: Marcello Aprille; [2006]

Nyckelord: ;

Sammanfattning: The awareness of the environmental problem along with an ever increasing demand for comfort cooling and refrigeration has brought a strong interest in new concepts of refrigeration technologies. By combining solar energy and absorption cooling, solar absorption refrigeration can offer a sound alternative to electrically driven vapour compression refrigeration. In this work, a simulation study of an innovative solar absorption refrigeration system is conducted. The system is intended for refrigeration at 5°C in warm and hot climates (South Europe and North Africa) and is composed of: medium temperature collector, single effect water ammonia absorption chiller and ice-encapsulated cold thermal storage. This configuration is justified by the high temperature difference between the chilled refrigerant temperature, about ?5 °C, and the ambient temperature, which could exceed 30 °C. In these conditions, the absorption chiller must be driven by a medium temperature collector. Moreover, the proposed chiller can be air-cooled, thus not making use of a bulky and expensive heat rejection system. Several simulations are conducted in order to investigate the system behaviour at different values of solar fraction and at three different locations: Rome, Tunis and Cairo. Also, two different medium temperature collectors are compared, a Fresnel linear reflector and a parabolic trough. The simulations are made with TRNSYS. User-defined TRNSYS types are made in order to characterise the absorption chiller and the cold thermal storage. The absorption chiller type makes use of performance data made available by the manufacturer and the cold storage type is modelled like a stack of uniform temperature layers of ice capsules surrounded by refrigerant. The mathematical model makes use of experimental equations, derived from literature, in order to represent the heat exchanged between refrigerant and ice capsules during ice to water and water to ice phase transition. The simulations have revealed a strong impact of the adopted control strategy on the system overall performance. Due to limitations in the maximum reachable solar loop fluid temperature, 300 °C, and the minimum reachable refrigerant temperature, -20 °C, two major problems are encountered: chiller part-load functioning, which occurs any time refrigerant temperature approaches ?20° C, and loss of available solar radiation, which occurs anytime the collector mirrors are set out of focus in order to maintain the solar loop fluid temperature below 300 ° C. According to the simulation results, with a chiller rate capacity of 13 kW and a load peak power of about 6 kW the system has proved to work with reasonable values of collector area and storage volume at 100% SF and at any of the selected locations. About 70 m2 of Fresnel collector area and 4 m3 of storage tank are necessary to cover the load year round. The parabolic trough would require less area, about 40 m2, but would cost more on the basis of the projected costs of the two solutions. Savings in both solar field area and cold storage volume are possible when using an auxiliary heater series connected to the collector in the solar loop. At 90% solar fraction, the system would require 70% of the collector area and 50% of the storage volume as calculated for 100% solar fraction. A simple economic analysis shows that the here presented concept has a good

economical potential when compared to an equivalent PV-electrical vapour compression solution. The overall system performance is higher with a PV based system, due to the high electrical COP of vapour compression chiller. However, the collector-absorption solution is more economical due to the cost of the solar field, which is lower than the cost of PV panels in its PV based counterpart.