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ORIGINAL ARTICLE

Performance evaluation for solar liquid desiccant air dehumidification system

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Abstract In this paper, a solar liquid desiccant air conditioning (SLDAC) system has been studied. The effect of changing evacuated tube collector area on the performance of the SLDAC system was fulfillment. This inquest was done over all a year in Borg Al-Arab city located in the Northern region of Egypt. Meteorological data, such as hourly average solar radiations and temperatures, were needed to achieve this research. The hourly cooling loads were determined by using Hourly Analysis Program (HAP) 4.7. These loads are wall, illumination, people, and equipment loads. Then, the hourly differences of different parameters such as amount of water absorbed in conditioner, amount of water desorbed in regenerator, hot water temperature and coefficient of the performance were calculated.

In addition, the maximum solar thermal energy was determined to meet the regeneration demand according to the hourly average solar radiation data. For 220 m^2 evacuated tube collector area, the maximum required heat energy is obtained as 38,286 kW h on December, while using solar energy, will save energy by 30.28% annual value.

1. Introduction

Humidity has a significant impact on indoor environments. High indoor humidity leads to uncomfortable and unhealthy environment. The basic problem is that all cooling coils, DX coil and chilled-water coil, are weak moisture removal devices. On the other hand, desiccants can be considered good devices to preserve comfortable and healthy indoor environments.

Desiccants are unique in that they can dry air without first cooling the air below its dew point. Once the desiccant is loaded with water, heat is used to return the desiccant to its "dry" state. The high electrical demand of the compressor in a conventional air conditioner is replaced by the need for thermal energy to regenerate the desiccant. This creates an important opportunity to use solar thermal energy for air conditioning. Liquid desiccant cooling is particularly well suited to solar applications as it requires low temperature heat (50–90 °C) and allows for high density loss and less energy storage in the form of concentrated desiccant. When comparing liquid desiccant systems to solid desiccant, or rotary wheel dehumidifiers, the ability to store energy is an important benefit for solar applications. The low cost of solar thermal energy makes SLDAC system become a competitive with natural gas desiccant air conditioning system [1]. This solar thermal energy can be provided by either flat-plate collectors or evacuated tube collectors. Flat-plate collectors are less expensive, as

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Nomenclature

c_p	specific heat at constant pressure, J/kg K
h	specific enthalpy, kJ/kg
h_{fg}	evaporation heat energy, kJ/kg
m^o	mass flow rate, kg/s
Q^o	heat energy, kJ
T	temperature, °C

Greek symbols

ω	humidity ratio of the air, kg_w/kg_a

Subscripts

a	air
c	conditioner
hw	hot water
s	solution
v	vapor

Abbreviations

COP	coefficient of performance
dbt	dry bulb temperature
Eff	efficiency
LDAC	liquid desiccant air conditioner
TRNSYS	transient system simulation tool

evacuated-tube collectors will have an installed cost that is around 1.5 times that of a flat-plate collector. However, the required area for the flat-plate collectors to produce the same thermal energy is bigger than that of evacuated-tube collectors. The selection of the collectors for a solar cooling system is a trade-off between their cost and performance. In general, the Coefficient of Performance (COP) for desiccant regeneration—defined as the thermal energy needed to evaporate a unit mass of pure water divided by the thermal energy supplied to the regenerator to remove the same mass of water from the desiccant—increases at higher temperatures [2].

Many contributions have been made in the research for environmental-friendly and CFC-free alternative dehumidification techniques and systems. The annual operating energy performance of a desiccant cooling system was studied by Kim et al. [3]. They also proposed the operation model which was used to estimate the energy saving potentials. They also made an energy comparison between the proposed system and the conventional variable air volume (VAV) system. The recent researches on solar liquid desiccant cooling were reviewed by Buker and Riffat [4] for different climates. For appraisal of the saving energy, Ronghui and Lin [5] implemented the operation performance of the SLDAC of a building in Hong Kong. The results showed that LDAC, driven by electricity, was not suitable for the commercial building due to the fact that huge electricity was needed in regeneration process. On the other hand, SLDAC provides promising saving energy in case of the presence of an additional source of cooling as well as cooling towers. Burch et al. [6] submit a new district cooling system. This system was new in that continuously hot liquid desiccant (LD) solutions were distributed to each home. Also it lowers LD flow rates by storing LD in central and local storage. A SLDAC system was simulated for five cities representing the four main climate regions by Qi et al. [7]. Results showed that sensible heat ratio had a seriously effect on the system's performance. The electricity energy needed in SLDAC system was highly reduced in humid regions where sensible-total heat ratio (SHR) was low.

Adriana et al. [8] used TRNSYS program to make a simulation and modeling of a hybrid liquid desiccant system (HLDS). They depend on performance tables to develop the modeling method. Kuala Lumpur city was chosen as a case study because it has high humidity and ambient temperatures throughout the year. A model, which predicts the regeneration rate, was inferred by Kim et al. [9]. This was done by statistically analyzing the experimental data measured from in fact liquid desiccant unit operated under different conditions. An optimization for central system parameters for different cities representing various climates was done by Qi et al. [10]. They depend on the Multi-Population Genetic Algorithm to get the optimal system performance. Data analysis elucidated that the climate changes had a large impact in choosing the operational system. Lowenstein et al. [11] made a comparison between a low flow LDAC air handling unit and a packed-bed liquid desiccant system when the ambient conditions were approximately 35 °C dbt and 16.9 g_{water}/kg_{dryair} humidity ratio.

The objective of the present investigation is to evaluate the performance of a solar liquid desiccant air handling unit using a numerical model. The scope of this study is aimed at studying the impact of changing solar collector area on absorption, desorption rates, and system coefficient of performance through summer season, also evaluating the annual energies consumption and the amount of energy saved by using the solar system with LDAC.

2. Materials and method

In Fig. 1, a schematic view of the SLDAC system is sketched. The main parts that the solar desiccant system consists of are evacuated tube collectors and a desiccant cooling device, which used the liquid desiccant to control humidity. Using evacuated tube collectors in SLDAC system has two benefits. First, it is simple construction, and second it is highly overall efficiency when installed with a SLDAC system.

2.1. Analyzing desiccant air condoning system

Fig. 2 shows the absorption and desorption process. It also labeled the inlet and the exit air or water temperatures as well as the liquid desiccant concentration through the absorber or desorber. The cooling or heating water flows inside each plate, with the desiccant falling down the plates in a thin film. Air is blown across the desiccant flow between the plates. Plate geometry is repeated with a 2.5 mm air gap between plates. The cross section of each absorber plate is 2.5 mm thick by 305 mm wide.