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Performance assessment of desiccant air conditioning system in an institutional building in subtropical climate

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Abstract

In hot and humid climate, the heating, ventilation and air conditioning (HVAC) system consumes more than 40% of the total energy consumption of the building. Therefore, it is necessary to find out the ways of reducing overall energy consumption of such power-hungry systems. The goal of this paper was to model and analyze the performance of desiccant air conditioning system in an institutional building in subtropical climate similar to that in Central Queensland and investigate whether the incorporation of a desiccant cooling system is able to reduce the energy consumption of the existing HVAC system. The analysis involved modelling the reference building using OpenStudio to determine its cooling/heating requirements. This is then followed by HVAC performance assessment of the existing VRF system, installed in the reference building, through developing a model in EnergyPlus (EP). The model is validated with on-site measured data recorded in building management system (BMS). Then, include desiccant air conditioning (DAC) system into the model to provide the dehumidification for the reference building to reach "thermal comfort" in terms of both relative humidity and temperature.

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Keywords: Air conditioning; desiccant cooling systems; building systems; performance measurement; subtropical climate

1. Introduction

Since the beginning of the 20th century, the cooling and dehumidification of homes and commercial buildings has transitioned from being a luxury to a necessity [1, 2]. Because of this, a significant amount of electricity being

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consumed through the use of air conditioning systems especially during peak hour i.e. in middle of the day when the maximum ambient temperature occurs also peaks. Consumption during these times increases the usage cost of the electricity which is typically generated using non-renewable energy source. In fact, approximately 86% of electricity supplied in Australia is generated from these fuel types, being 73% coal and 13% natural gas [3]. Hence, due to the increase in energy demands, this directly contributes to more fossil fuels being burnt. As an example, HVAC and refrigeration systems consume 46% of the South Australia's total produced electricity. With such a large percentage of power usage, HVAC and refrigeration systems can be linked to the contribution to Australia's carbon emissions.

Considering that Australia's energy is generated centrally with heavy reliance on traditional energy sources such as "cheap and abundant" coal, this manner of supplying power encourages the emission of greenhouse gases which is detrimental particularly towards the surrounding environment and the community. Attempts were made to increase the efficiency of existing AC designs by using economizers to help alleviate power consumption hence less fossil fuels. However, it operates by recycling air within the building with encourages virus, dust, germ, and mould to be transmitted through the system's ventilation [4]. With the integration of desiccants into the air conditioning system this problem can be mitigated as desiccants have properties that enable the removal of moisture and latent heat from the process air, consequently, improving indoor air quality. Additionally, this process can be done with much less energy consumption due to the solar-assisted heating [5-7] Therefore, the carbon footprint and the power usage by traditional air conditioning systems can be significantly reduced. The goal of the project is to analyse the performance of desiccant air conditioning system in a subtropical climate similar to that of Central Queensland. Therefore it is ideal for the simulated experiment to be conducted based from the location of the CQU main campus at North Rockhampton, Queensland. The reference building in the experiment is Building 29, one of the engineering buildings at CQU.

The analysis involves modelling the reference building using OpenStudio to determine its cooling/heating requirements. This is followed by HVAC performance assessment of the existing VRF system installed in the reference building through EnergyPlus (EP) [8]. Then, inclusion of a desiccant air-conditioning (DAC) system into the model is done to provide the dehumidification for the reference building to reach "thermal comfort" in terms of relative humidity. Additionally, the current energy consumption of the reference building is collected to serve as a basis of comparison and validation against the simulated results in OpenStudio and EnergyPlus. Appropriate conclusions and recommendations are then provided in the completion of this investigation.

With the completion of this investigation, valuable information, data, key measures and decision-making tools can be provided to designers, developers, and engineers about the viability of the desiccant air conditioning system to operate in a harsh subtropical geographical location. With further studies succeeding this investigation in improving efficiency and performance competitiveness of the desiccant system can be used as a potential energy-saving for the energy-hungry traditional vapour compression air conditioning units with the assumption that financial expenditures can be brought down to a more competitive level.

2. Reference Buildings

Building 29 of Rockhampton campus of Central Queensland University, Australia, was used as a reference building for simulation. The location details of the building are; latitude -23.4, longitude 150.48, elevation 15 m and time zone 10. The building consists of 3 levels and each floor is completely air-conditioned. Access to the upper floors of the building can used at the south end where a stairwell is located. There is also a walkway that connects the upper floors to the adjacent building 28, another 3-story building. The ground floor consists of staff 3 staff offices, a lecture theatre, toilets for male, female, and the disabled, and a shower room. It is important to note that the toilets and the shower room are not being air conditioned. The first and second floors have a similar floor plan consisting of two studio rooms per floor equipped with several monitors (CPU and accessories not included) for student use and large interactive projectors per studio room. There are also 2 breakout rooms per floor adjacent to one kitchenette per floor. Typical usage of the building is for student use e.g. lectures/tutorials/workshops. The ground floor consists of Energy consumption of the building can come from university computers, screen projectors, monitors, power outlets, lighting, kitchen appliances in the kitchenette, and exhaust fans for ventilation of non-air conditioned rooms such as the shower room at the ground floor. The HVAC system is the main energy consumer of the building. The HVAC system being used in the building is a Variable Refrigerant Flow (VRF) system.