# Solar Air Conditioning System Using Desiccant Wheel Technology

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*Abstract:* - The electrical energy consumption in Malaysia has increased sharply in the past few years. Modern energy efficient technologies are desperately needed for the national energy policy. In this paper, a new design of desiccant cooling is being developed at the Solar Energy Research Institute, National University of Malaysia, Malaysia. The new conception of desiccant cooling can be an energy saving and permits to produce heat or cool by using solar energy without polluting the environment. Desiccant cooling systems have been used successfully in northern Europe and a number of studies have demonstrated that solar energy can be used to drive the system in this region. However, to date, desiccant cooling has not been used in Malaysia. This paper presents the results of a study, in which a solar desiccant cooling model will used to evaluate the potential for using solar power to drive a single-stage desiccant cooling system in Malaysia. The study demonstrates that solar desiccant cooling is feasible in Malaysia, provided that the latent heat gains experienced are not excessive. However, if the relative humidities experienced are too high then desiccant cooling becomes impracticable simply because the regeneration temperatures required are excessive.

*Key-Words :-* Solid desiccant; Desiccant cooling; Air-conditioning; Solar thermal energy.

## 1 Introduction

Desiccant cooling systems are energy efficient and environmentally benign. According to one estimate, desiccant dehumidification could reduce total residential electricity demand by 25% or more in humid regions[1], providing a drier, cleaner, more comfortable indoor environment with a lower energy bill. Desiccant systems allow more fresh air into buildings, thus improving indoor air quality without using more energy. Desiccant systems also displace chlorofluorocarbon-based cooling equipment, the emissions from which contribute to the depletion of the Earth‘s ozone layer.

When fresh outdoor air is brought into a building, it often carries a high humidity load relative to the building‘s internal latent load. Conventional vapor-compression cooling systems are not suited to efficiently treat large humidity loads. To sufficiently dry the air in many applications, vapor-compression systems must be operated at low temperatures, which reduces their efficiency and results in inefficient reheating of the dry, cold air to achieve some degree of comfort. Additionally, matters are made worse by common use of oversized compressors controlled by dry-bulb set points. This leads to short-cycling, which can reintroduce condensate from a wet cooling coil back into the supply air.

Currently, desiccant cooling and dehumidification systems are being used successfully in industrial and various commercial markets and provide clear advantages in many applications throughout the United States. Desiccant cooling systems are used to improve the indoor air quality of all types of buildings by efficiently controlling moisture in large quantities of fresh, ventilation air. In these systems, a desiccant removes moisture from the air via a process called sorption, which releases heat and increases the air temperature. A combination of heat exchange with ambient air and evaporative or conventional cooling coils then cools the dry air. Temperature and humidity loads are very effectively and efficiently met by separating them in this way. The desiccant is then dried out (regenerated) to complete the cycle using thermal energy supplied by natural gas, waste heat, or the sun. Commercially available desiccants include silica gel, activated alumina, natural and synthetic zeolites, titanium silicate, lithium chloride, and synthetic polymers.

## 2 Energy Demand in Malaysia

The demand for energy is expected to increase worldwide over the next 24 years [2], both in the industrial countries and particularly in the developing countries like Malaysia where rapid economic growth is expected. Fig. 1 shows the energy demand for Malaysia in the year 1999, 2002, 2005 and estimated values for 2010 [3]. It can be seen that the energy demand in Malaysia increases rapidly as the energy demand increase almost 20% within the last 3 years (from 1999 to 2002). The energy demand is further expected to increase to 18,000MW by the year 2010. In order to meet the increasing demand of energy in Malaysia, a major challenge facing the power industry will be having an effective and sustainable energy policy. An effective and sustainable energy policy has two main considerations. The first consideration is to increase access to affordable, modern energy services in countries that is lacking and secondly, to find the mix of energy resources and technologies (efficiencies) that will reduce the adverse environmental impacts of providing necessary energy services [4]. Since all the urban areas and 93% of the rural areas in Malaysia have access to electricity [5], the crucial challenge facing the power sector in Malaysia currently is the issue of sustainability that is to ensure the security and reliability of energy supply and the diversification of the various energy resources.

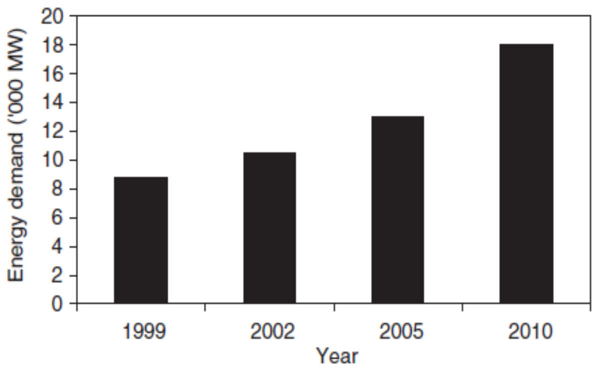


**Fig. 1** Energy demand in Malaysia. Sources: Thaddeus (2002) and UK Trade & Investment (2003)

The question of security and reliability of supply is critical, to ensure smooth implementation of development projects to spur economic growth in Malaysia while diversification of energy resources is critical to ensure that the country is not dependent only on a single source of energy [6]. At the same time, these challenges must be met without having adverse effect on the environment to ensure sustainability. Therefore, the aim of this paper is to describe the various energy policies adopted in Malaysia to ensure long-term reliability, sustainability and security of energy supply. The role of both, non-renewable and renewable sources of energy in the current Five-Fuel Diversification Strategy energy mix will also be discussed. Apart from that, this paper will also describe the various alternative energy and the implementation of energy efficiency program in Malaysia.

## 3 Alternative Energy

### 3.1 Solar

Malaysia solar power or also known as photovoltaic (PV) system is estimated to be four times the world fossil fuel resources [7]. In Malaysia, the climatic conditions are favorable for the development of solar energy due to the abundant sunshine throughout the year. The solar radiation in Malaysia ranges from 6.5 kwh/m2 in the months of January and drops lower to 6.0 kwh/m2 in the months of August [8]. A PV system consists of several solar cells that convert light energy into electricity. Photovoltaic are an elegant means of producing electricity on site, directly from the sun, without concern for fuel supply or environmental impact. Solar power is produced silently with minimum maintenance, no pollution and no depletion of resources. Photovoltaic system are also exceedingly versatile and can be used to pump water, grind grain and provide communications and village electrification in situations where no electricity is available [9]. At the moment, the utilization of solar power or PV system in Malaysia is only limited to solar water heating systems in hotels, small food and beverage industries and upper middle class urban homes. It was estimated that there are more than 10,000 units of domestic hot system using PV system at the moment in Malaysia [10]. Although PV system has tremendous potential, especially for remote areas in Malaysia, the cost of PV panels and technology is still too expensive for mass power generation. In order to reduce the cost of PV system, Malaysian Energy Center (PTM) embarked on a project named Malaysian Building Integrated

Photovoltaic (MBIPV). The aim of the project was to incorporate PV system into the design of the building and become the main-stream of power production for the building. However, a cost reduction of 20% is required before PV system can become a viable source of energy as compared to the energy produced from fossil fuels or natural gas [11].

### 3.2 Solar Radiation Malaysia

Malaysia lies entirely in the equatorial region. The climate is governed by the regime of the north-east and south-west monsoons which blows alternatively during the year. The period of change between the two monsoons is being marked by heavy rainfall. The country experiences more than 170 rainy days per year. Ambient temperature remains uniformly high throughout the year, ranging from 26.0 to 32.0 centigrade. Most locations have relative humidity of 80-88%, rising to nearly 90% in the highland area, and never fall below 60%. The monthly average daily solar irradiation in Malaysia is 4000 – 5000 Whr/m2, with the average monthly sunshine duration ranging from 4 to 8 hours [12].

## 4 Desiccant Cooling

Desiccant cooling consists in dehumidifying the incoming air stream by forcing it through a desiccant material and then drying the air to the desired indoor temperature. To make the system working continually, water vapour adsorbed/absorbed must be driven out of the desiccant material (regeneration) so that it can be dried enough to adsorb water vapour in the next cycle. This is done by heating the material desiccant to its temperature of regeneration which is dependent upon the nature of the desiccant.

A desiccant cooling system, therefore, comprises principally three component, namely the regeneration heat source, the dehumidifier (desiccant material), and the cooling unit.

The efficiency of desiccant system depends strongly on the Sensible heat Ratio (SHR). The SHR is defined as the ratio of the sensible heat gain to the sensible and latent heat gain of the space being conditioned. A low value of this quantity means that the total cooling load is predominately the latent load, in which situation desiccant cooling is demonstrated to be effective and economical.

### 4.1 Working principle of a solid desiccant cooling system

Solid desiccants are impregnated in a dehumidifier bed, usually a rotary disc which slowly rotates between the process and regeneration air streams. As the hot and humid process air passes through the desiccant wheel, the moisture is removed by the desiccant, and its temperature increases. The temperature of this process air, which is now hotter and drier, is reduced to the desired comfort conditions by means of sensible coolers (e.g. rotary heat exchangers, evaporative coolers, and cooling coils). The warm and humid return air from the conditioned space is further heated up to the required regeneration temperature of the desiccant and this regeneration stream of air is passed through the desiccant wheel to remove the moisture from the desiccant.

Advantages of using desiccant cooling systems include the following: (1) very small electrical energy is consumed and the sources for the regenerating thermal energy can be diverse (i.e. solar energy, waste heat, natural gas); (2) a desiccant system is likely to eliminate or reduce the use of ozone depleting CFCs (depending on whether desiccant cooling is used in conjunction with evaporative coolers or vapour compression systems since sensible and latent cooling occur separately; and, (4) improvement in indoor air quality is likely to occur because of the normally high ventilation and fresh air flow rates employed. Also, desiccant systems have the capability of removing airborne pollutants.

## 5 Modeling of the Desiccant Air-Conditioning System

Performance of a desiccant system for space air-conditioning depends to a group of parameters and/or conditions, implicating the system's operation parameters, environmental conditions and space requirements. The development of models is necessary tool for the study of the relation of the above-mentioned parameters, on a design, control strategies, as well as performance analysis basis.

The modeling of the desiccant system, for Malaysia presented in Fig.2, refers actually to integration of models of individual's components of the system (desiccant wheel, rotary heat exchanger, and humidifier.

Figs. 2 and 3 show a schematic installation of the solar desiccant cooling system and the air evolution in the psychometric chart. In order to maximize the effect of the latent heat of vaporization of water, the

ventilated air flow is first of all dried out in a “desiccant wheel” [A→B]. It is next cooled in a sensible heat exchanger (recovery wheel) [B→C] and at last cooled down adiabatically [C→D through a humidifier. The operating of such a system necessitates a regeneration air flow. The air is first extracted from the building, then after being cooled down adiabatically [E→F] in a humidifier, it cools the air of the process in the recovery wheel [F→G]. The last operation is to regenerate the desiccant material [H→J] with the return air stream that has been heated [G→H→I]. The generation heat can be taken from solar collector’s back-up energy, via a storage tank. The required temperatures are in between 50 and 85$^{o}$C and therefore vacuum tube solar collectors can be used.
The desiccant air-conditioning system is open cooling cycle, which means that the refrigerant fluid is the ambient air. That is why the outdoor and indoor air conditions influence strongly its operation. The operation principle of the desiccant wheel, the dehumidifying capacity of the wheel depends to the rotational speed of the wheel, flow rate (actually the velocity of air in the face of the wheel) and the temperature of the conditions (temperature, absolute humidity), as well as to the absolute humidity of the regeneration stream.

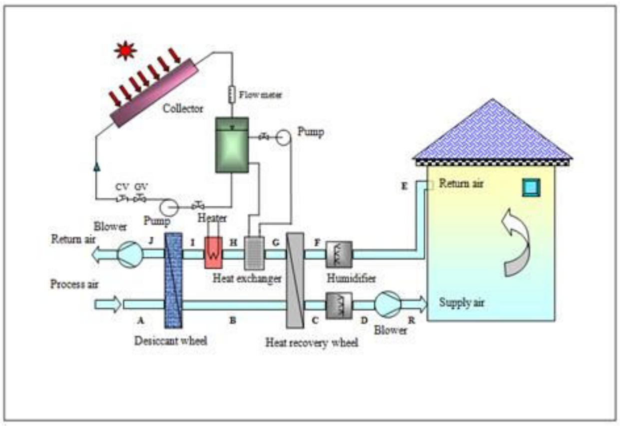


**Fig. 2** Schematic of the solar air conditioning system using desiccant wheel.

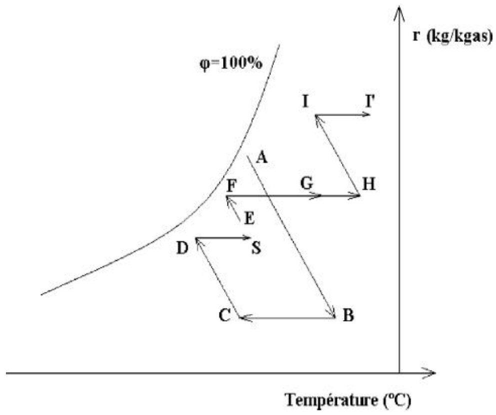


**Fig.3** Cycle’s psychometric representation

## 6 Economic Issues

All solar air cooling technologies (SAC) system present good figures for primary energy consumption. The best performance are seen in system with integrated heat pumps and small collector areas. The economics of these SAC system at current equipment costs and energy prices are acceptable. They become more interesting in the case of public incentives of up to 30% of the investment cost (Simple Payback Time from 5 to 10 years) and doubled energy prices [1].

## 7 Conclusions

Rotary desiccant air conditioning is a typical thermally activated technology, which mainly consumes low grade heat sources as solar energy, district heating, waste heat, etc., thereby alleviating the peak electric demand caused by traditional air conditioning systems. Especially, based on the recent progress in desiccant material and system configuration, more and more practical applications have been implemented around the world. While the most widely used desiccant materials in market,namely silica gel and lithium chloride, are either limited by dehumidification capacity or problematic for crystallization and corrosion, composite desiccants combine the merits of existing desiccants and overcome these problems by confining salt to porous host adsorbent, and have been recognized as a better choice. Additionally, the reduction in regeneration temperature and the increment in dehumidification capacity over a wide range will be of great benefit to utilizing low-temperature heat and expanding the application of desiccant air conditioning.

The majority of existing rotary desiccant air conditioning systems originates from the typical basic configurations, such as ventilation cycle, recirculation cycle and Dunkle cycle. And these cycles are appropriate for different applications, for example, ventilation cycle is recommended for conditioned-space with high outside air requirement, whereas recirculation cycle is suitable to space requiring much less fresh air. Besides, on the basis of the basic system configurations, some advanced technologies, namely, staged regeneration, isothermal dehumidification, hybrid desiccant air conditioning, and desiccant air conditioning producing both dry air and chilled water, have been developed and investigated to lower the reactivation requirement, ensure the operation stability, and improve the thermal utilization rate and energy saving potential. Among these technologies, staged regeneration reduces the consumption of high temperature heat by pre-heating and pre-regenerating the desiccant and is advantageous in reducing the size and effectiveness requirement of heat exchanger; isothermal dehumidification minimizes the irreversibility of dehumidification via adopting multi-stage design and intercoolers, which results in much lower regeneration temperature and less heat consumption; hybrid desiccant air conditioning is most researched due to it integrates the merits of desiccant dehumidification system and other air conditioning systems, downsizes system size and improves system performance significantly; desiccant air conditioning producing both dry air and chilled water is a novelly proposed technology using desiccant dehumidification and regenerative evaporative cooling and is worthwhile for future research for its outstanding property of realizing independent temperature an humidity control without any assistance from VAC unit.

In conclusion, further improvement in energy utilization rate, reduction in cost and size, and standardization in design and production are the key issues faced by the rotary desiccant air conditioning technology for achieving more extensive application.

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