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Integrated systems for air conditioning and production of drinking water – Preliminary considerations

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Abstract

The water vapor condensation in the HVAC system chillers can be employed to increase the sustainable use of resources by using the condensed water for domestic consumption. Preliminary investigation on a design of an integrated HVAC system for the air conditioning of a hotel combined with water production is presented. The calculations are referred to the climatic conditions of the Arab Emirates coast. The preliminary calculations show that the produced water could be efficiently used for various destinations and, in some cases, its treatment could be finalized to produce drinking water.

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1. Introduction

The efforts to produce drinking water are the subject of several studies, for developing suitable technologies that could be used mostly in areas where the lack of water determines high difficulties for its supply and consequently high costs [1, 2].

The capabilities of various systems of water extraction from seawater, atmospheric water vapor, soil have been exploited to produce commercial installations, finalized mainly to the emergencies

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(earthquakes, floods, and when there is not drinking water temporarily available).

The economic aspects sometime have been considered of secondary importance, even if, in more recent times, the efforts to reduce energy consumption are assuming higher relevance.

An interesting application regards the HVAC systems: cooling the air below its dew point (mostly in summer times) is a process that allows its dehumidification, producing a lot of condensed water usually thrown away. This amount of condensate could be used for the building needs, avoiding water waste.

Therefore, an integration between the air conditioning system and a water extraction system could be a good mean to achieve energy consumption optimization and sustainable use of resources. In this perspective, the water production (drinking water, if needed) may be considered almost a free benefit, obtained as a secondary result of a smart HVAC system design.

Obviously, in order to obtain good results by the application of such integrated system, two conditions are fundamental: firstly, a real necessity of indoor air-conditioning, secondly, compatible external hygrometric conditions. For this purpose, a case-study represented by a typical use of a HVAC system (bank, hotel, shopping centre) has been analysed, to obtain the maximum efficiency both for the air conditioning and for water production.

Several simulations have been conducted, aimed to assess the daily water demand, the needed power and the optimal ratio between the produced water and the air conditioning loads.

The present work is a first step of the sizing of an integrated system, suitable for a new building, a hotel: it is calculated under the particular climatic conditions of the Arab Emirates coast. The Gulf countries provide to their water needs with some of the world's largest desalination plants, however they are rising to the challenge with some of the most sophisticated water capture innovations. The Abu Dhabi Farmers' Services Center (FSC) has spearheaded G-Earth, a technology that extracts condensation from the air to provide water for Abu Dhabi greenhouses [3, 4]. This application seems to follow the same original criteria. For the present analysis, the following steps were considered:

- a research of a representative climate of coastal Arab cities;
- the system configuration preliminary design for a typical hotel destination;
- the theoretical hourly water production calculation and the water demand supply evaluation.

A further step of the research will consider the sizing and the comparison between a "traditional system", suitable only for air conditioning, and an "integrated system", suitable both for air conditioning and water extraction, in order to evaluate the energy convenience and the cost effectiveness of the second one. In the following paragraphs, some considerations on the first steps are presented.

2. HVAC system preliminary configuration

2.1 Climatic conditions

In order to consider a representative Arab Emirates coastal climate, Abu Dhabi was chosen as the representative city: its climatic conditions are very similar also to the ones of Dubai (Fig.1). The analysis was performed by means of the hourly average monthly data [5]. From these data, it is interesting to highlight that in January, February and December temperatures are generally under 26°C. In particular, in January, temperature is always under 23°C, while in December and in February temperature is over 25°C (only for few hours, as it results from the hourly data observation). During those months, the specific humidity is always below 10 g vapor/ kg dry air.

For the design outdoor air conditions, reference temperature and relative humidity values must be chosen as representative of the worst condition that can reasonably take place, because the HVAC system must be able to work even in bad conditions.

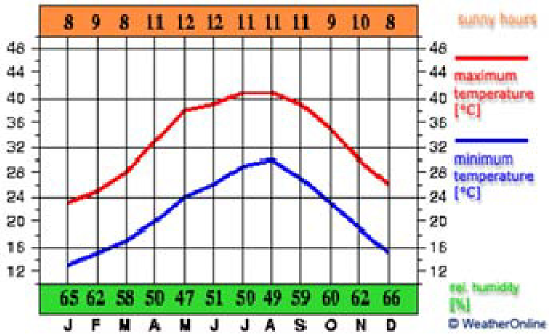

Fig. 1. Abu Dhabi max and min monthly mean temperatures

Referring to the climatic data of Abu Dhabi, 35°C of temperature and 60% of relative humidity were chosen. From those values, an enthalpy of 90.1 kJ/kg can be calculated. That value is always slightly higher than the outdoor monthly maximum enthalpy values (Fig.2), and therefore it is the reference assumed, in order to proceed with the systems sizing.

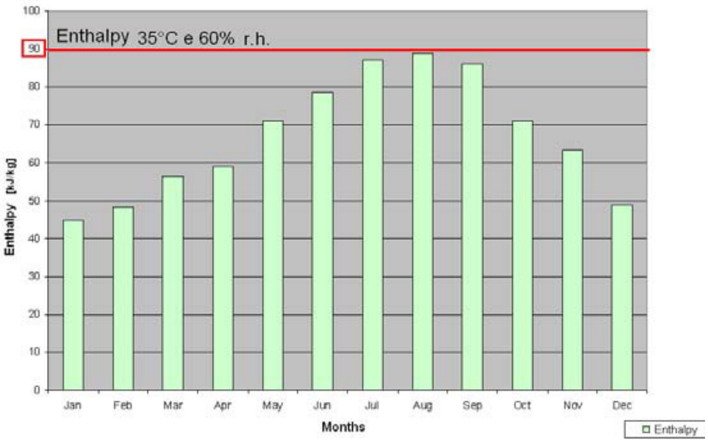

Fig. 2. Maximum outdoor enthalpy values

Note that the minimum difference between the chosen enthalpy value and the real maximum outdoor enthalpy is about 1 kJ/kg, hence the chosen value doesn't bring to oversize systems.

2.2 Hotel needs configuration

For the preliminary calculations, a luxury hotel configuration is chosen as the standard new building on which the integrated system installation will be considered. In particular, it is considered with 300 private rooms, suitable for two guests each, and several common areas as restaurants, bars, casino, breakfast rooms, conference rooms, reception hall, shopping area.

Each room, due to the hotel high classification, has a water supply of 500 liters/day: the whole water requirement of the building is 150 m^3/day that includes guests' water consumption and all the other hotel services needs. Regarding the indoor climatic conditions, it is assumed to maintain 20°C and 60% RH in all seasons, in the whole building.

The calculation of sensible and latent loads that must be supplied by the above mentioned system was performed in a detailed way. The assumed data for the calculations were: reference module of room usable area is 28 m^2 while bathroom area is 8 m^2, height 3 m, net conditioned volume 84 m^3. Wider rooms and suites were considered multiple of a single module. The mean heat transmittance of opaque envelope U = 0.4 $W/(m^2K)$, windows, U = 2 $W/(m^2K)$. A building of 20 floors was considered, 20 rooms each floor, over the first five ones, in which are placed common areas. Sun heat loads were calculated using the sol-air temperature method. Heat losses for each room were calculated considering that all the other rooms were empty and not conditioned, while all the common zones were considered conditioned. Extra flux directed to the sky was not considered. The hotel has considered without a specific orientation, to obtain more general results from the calculation. Air infiltration was considered, and also the heat loads due to occupation and electrical equipment. Heat load calculation was performed for 12 different room configurations, to take into account the geometrical configuration of the envelope. A mean value of 2.4 kW of heat loads results by the calculations (however in the HVAC design, the detailed loads were considered for each room).

2.3 HVAC system configuration

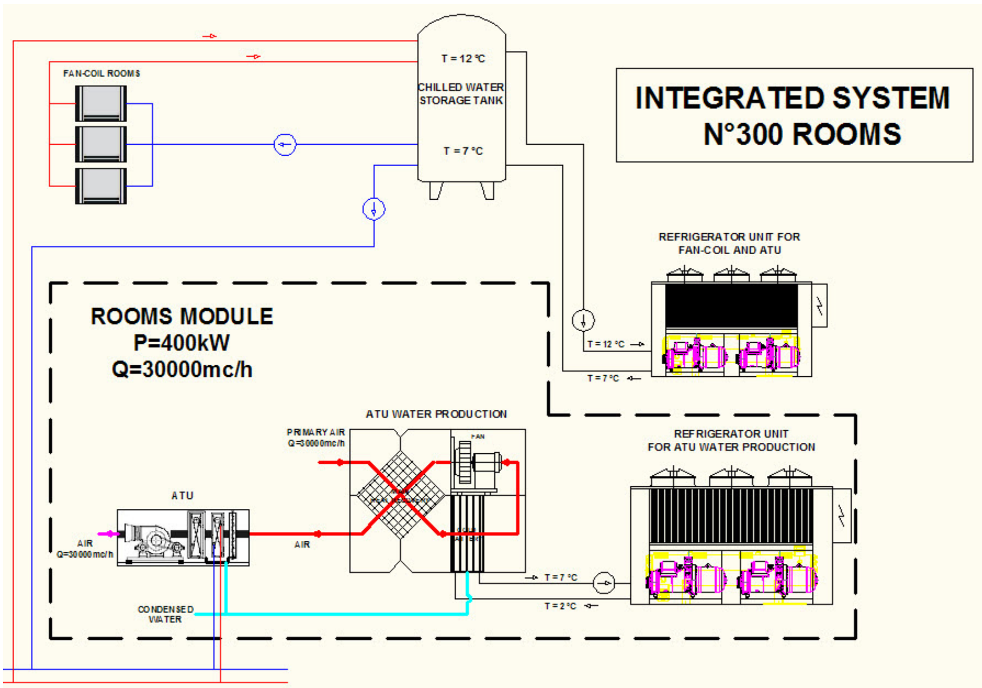

Fig. 3. Air treatment unit dedicated to rooms

The HVAC system must be sized taking into account outdoor and indoor thermo-hygrometric conditions and the global heat load of the building.

It will be composed by two sections: one that threats the air for common areas and the other (fan-coil and primary air supply) dedicated to private rooms and in particular to fan-coil supply and primary air control. The integrated system has been calculated with the following gross characteristics:

- total cooling power equal to 3600 kW (corresponding to the power supplied by the chiller, 2400 kW, and the power recovered from a suitable heat recovery system, 1200 kW);

- air flow treated 180000 m^3/h;
- minimum air temperature in the inlet section of cooling unit 7°C;
- inlet and outlet water temperature in the chiller 1°C - 6°C.

The air that comes from the water extraction loop, after the heat recovery, is used as fresh air for both the common areas and the private rooms.

The total cooling power of 3600 kW is divided into six modules of the same size. Each module size is 600 kW (400 kW delivered by the chiller and 200 kW recovered by the heat recovery system) and it treats 30000 m^3/h air flow.

The integrated system analysed in the present research is designed for the production of water and simultaneously for the air conditioning of the hotel with the characteristics supposed above. It is optimised to maximize the production of water by condensation in the heat exchanger of the chiller. In particular, the module that has been calculated for private rooms supply is here described (Fig.3).

The plant is composed of:

a) treatment unit for the production of water, with 1 heat recovery unit, 1 cooling coil, 1 fan.

b) treatment unit for air handling with 1 cooling coil, 1 fan, 1 refrigeration unit that provides the air treatment unit, 1 pump for the refrigerant circulation.

3. Water flow theoretical production and supply evaluation

Once the representative climate was defined and the preliminary system configuration was assumed, it was possible to do a preliminary evaluation of the extractable water by a single module system, on the basis of hourly climatic data. Results are shown in figure 4.

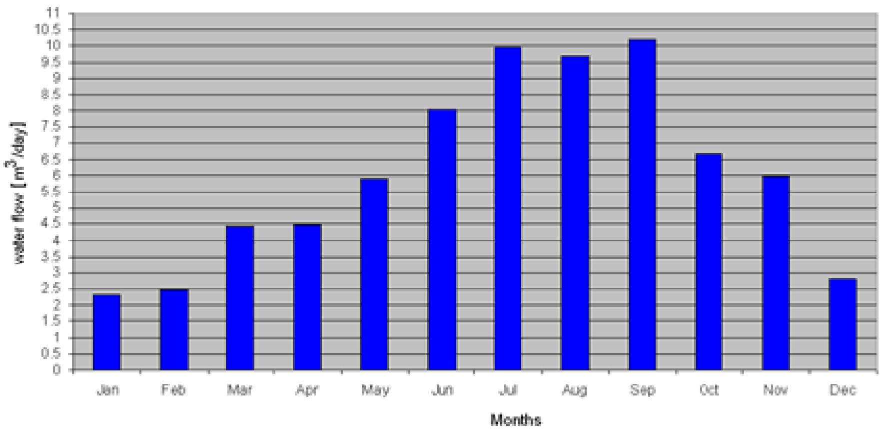

Fig. 4 - Monthly average extractable water flow

In the winter months, water production is not high, because it is less than 3 m^3/day for each module. In that period of the year is also possible that the heat load of the system could be small. In June, July, August and September, there's the maximum water extraction. In particular, in September water production achieves 10.2 m^3/day for each module.

In Table I the monthly percentage of hotel water requirements supplied by the integrated system are shown. It can be highlighted that from July to September it is possible to supply over 38% of water requirements (and in certain cases over 40%), while the average yearly supplied water is over 24% of the total needs. Considering only the months during which the air conditioning system works with full load, the water extraction can supply over 29% of the requirements.

Table I - Water demand supplied by extraction from air

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.2%	9.9%	17.7%	17.9%	23.6%	32.2%	39.9%	38.7%	40.9%	26.8%	23.9%	11.2%

Supposing the external conditions fixed to 35°C of temperature and 60% of relative humidity, the whole water production of the six modules could be evaluated in about 70.3 m^3/day, representing 47% of requirements.

It is important to highlight that condensate water, that comes from a standard HVAC system, is not pure, neither suitable for human use. This is because heat exchangers, ATU filters, condensate basins, pipe system and collecting systems, are not designed in order to guarantee any kind of sterilization or mineralization of the condensate. The condensate quality is strictly connected to environment air quality. If the external air pollutants are not removed, it is possible to find some of them in the condensate. Where water is collected, often bacteria prosper. Moreover, it is well known that condensed water is very poor of minerals, and demineralized water is not suitable for drinking. Therefore, the integrated system is not designed only as a HVAC system, but it contains a water treatment facility that allows to obtain drinking water. Mechanical filtration (not only for air), adsorption, ultraviolet germicidal irradiation and ad hoc designed mineralization, are planned to change simple polluted condensate in drinking water.

4. Conclusions

The preliminary investigation on an integrated HVAC system for the air conditioning of a hotel combined with water production has been discussed. The climatic conditions of the Arab Emirates coast were assumed for the analysis of a case-study. The results show that a significant amount of water could be produced by a HVAC system, optimized for this aim, but used also for air-conditioning.

Further analyses will be prosecuted to show how much profitable the treatment of the condensed water to use as drinking water, if the costs can be considered affordable.

The study would demonstrate the competitiveness of the production of water from the air, by means of the comparison between a traditional and an optimized system, and would evaluate the production costs of drinking water. From a deeper technical and financial analysis, that will be further developed, the solution will be shown as an interesting sustainable way to reduce water consumption.

Acknowledgements

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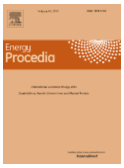

Biography

Anna Magrini – PHD, Professor of Applied and Building Physics, member of working group of ISO/TC163 Thermal performance of buildings and components (CEN, European Committee for Standardisation). Expert member of Italian Standardisation Technical Committee 102/SC01 “Insulating materials – calculation and measurement methods. Researches: energy performance, moisture problems and environmental sustainability of buildings