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Simulation of a solar cooling system.

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Abstract. In this technical and economical analysis of a building air-conditioning system, the main goal is to analyse what variables have effect on the system. To obtain the wanted temperature in the room we work, it is necessary to overcome the external conditions of temperature and radiation. However, this external conditions depend on the geographical situation, they change constantly and it is obvious that engineers cannot have an influence on current weather conditions during the making decision process. For all these reasons, once the architectural design of a building is decided, the engineer can only take decisions regarding some parameters like area of solar collectors , storage tank volume and input temperature of the absorption chiller. This article focusses on the execution of simulations in the aim of determining the optimun value of these parameters, paying attention to technical and economical goals.

Key words

Simulation, Radiation, Solar, Efficiency, Absorption.

1. Introduction

The traditional analysis will take into account the more adverse conditions for the installation. A system capable of overcoming them will be designed. However, some decisions regarding the design of this system like storage tank volume, area of solar collectors and input temperature of the absorption chiller will be decided by the engineer. In the best case, there are some equations published by different authors that relate these parameters to the thermal loads. This article contains the results of an hourly simulation of the system and analyse how the value of these variables affects it economically and thermally.

Global warming presents a serious threat, the reconsideration of a more sustainable economic model requires more active participation and agreement between the largest number of countries.

In the concern for energy conservation, energy efficiency in the building is a key field, also it is very important the policy changes introduced with the CTE. The precise calculation of thermal loads is important for a deeper study of building energy, allowing better design of air conditioning equipment, which undoubtedly contributes to a large energy savings. For this reason, EnergyPlus program has been chosen to make the calculation of air conditioning demands allowing a refined calculation, since they have many variables into account, and it can achieve results with shorter time intervals.

There are no clear results, no definitive studies on the technology of solar cooling system. Besides influence that can have the environment (weather, solar radiation, building construction features, etc.). In the operation of an air conditioning system, there are other variables, specific to the facility, which may dramatically influence measure the energy cost of building and cost of the HVAC system, so we need a detailed study

2. Building's profile

This is a three storey building with 160 m^2 per floor. Each floor is divided into two offices, as shown in the background (Fig 1).

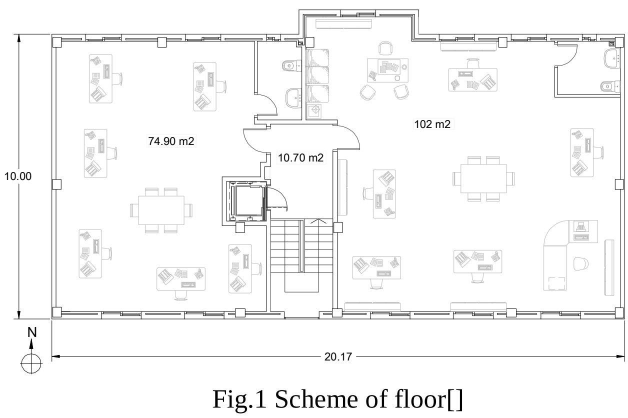

Fig.1 Scheme of floor[]

The use of the building is offices, occupancy hours 8:00 to 14:00 and 16:00 to 18:00.

3. Heat load calculation with energy plus

It must be developed a model that represents the building to study of building energy performance. This model includes all parameters that affect its energy consumption.

EnergyPlus difference in three main blocks to solve the energy flow balance in each of them, taking into account the influence that each block has on others for every moment, which means that the three systems involved (building, system and plant) must be solved simultaneously in an integrated manner.

The basis for the zone and system integration, Taylor.(1990, 1991), incorporates a shortened simulation time step, typically to between 0.1 and 0.25 hours, and uses a time-marching method having the zone conditions lagged by one time step. The error associated with this approach depends significantly on the time step. The smaller the step size the smaller the error, but the longer the computation time.

The time constant, τ , for a zone is on the order of:

$$\tau \approx \frac{\rho V C_P}{\left|\dot{Q}_{load} + \dot{Q}_{sys}\right|} \qquad (1)$$

where the numerator is the zone air heat capacitance and the denominator is the net rate of heat energy input.

A heat balance on the zone has to be solved:

$$C_z \frac{dT_z}{dt} = \sum_{i=1}^{N_{sl}} \dot{Q}_i + \sum_{i=1}^{N_{surfaces}} h_i A_i (T_{si} - T_z) + \sum_{i=1}^{N_{zones}} \dot{m}_i C_p (T_{zi} - T_z) + \dot{m}_{inf}\, C_p (T_\infty - T_z) + \dot{Q}_{sys} \qquad (2)$$

Where:

$C_z \frac{dT_z}{dt}$ energy stored in zone air

$\sum_{i=1}^{N_{sl}} \dot{Q}_i$ sum of the convective internal loads.

$\sum_{i=1}^{N_{surfaces}} h_i A_i (T_{si} - T_z)$ heat transfer due to infiltration of outside air.

$\sum_{i=1}^{N_{zones}} \dot{m}_i C_p (T_{zi} - T_z)$heat transfer due to interzone air mixing

$\dot{m}_{inf}\, C_p (T_\infty - T_z)$heat transfer due to infiltration of outside air

$\dot{Q}_{sys}$ system output.

Thereafter it is necessary to describe the building geometry, materials, surfaces, schedules, controls and thermostats.

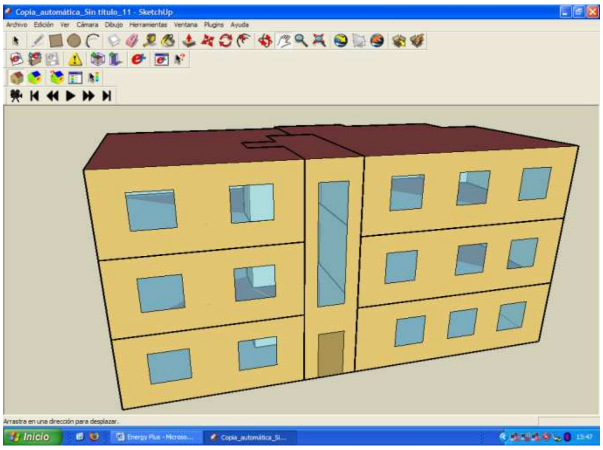

Fig. 2 Google Sketch Up

The temperature control is dual operating point, with temperature limit.

The temperatures are defined:
Starting up the heating:
- Winter 20 º C
- Summer 17 º C

Start of cooling:
- Winter 27 º C
- Summer 25 º C

We must choose which variables should be the outputs of the program. In this case, the results shown are the heating and cooling loads of each area specified. The output file consists in 8760 data vectors, which are the heat loads of each zone for each 8760 hours a year.

Below are the hourly demands for the building, it have been calculated with Energy Plus. The blue lines correspond to the hourly demands of heating, and brown lines correspond to cooling demands.

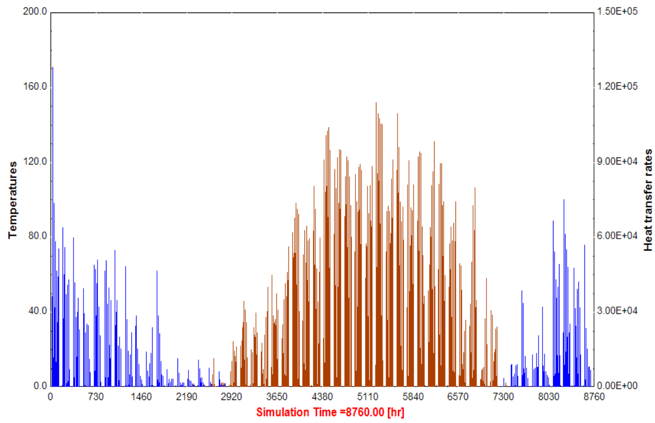

Fig. 3 Heat transfer request in Madrid [kJ/h]

4. Solar system set up

To perform the simulation, first it is neccesary to define an installation and its components. The installation consists of :
- Solar collectors.

• Hot water tank.
• Boiler support.
• Output heating and hot water.
• Absorption Chiller.
• Cooling tower.
• Pumps.

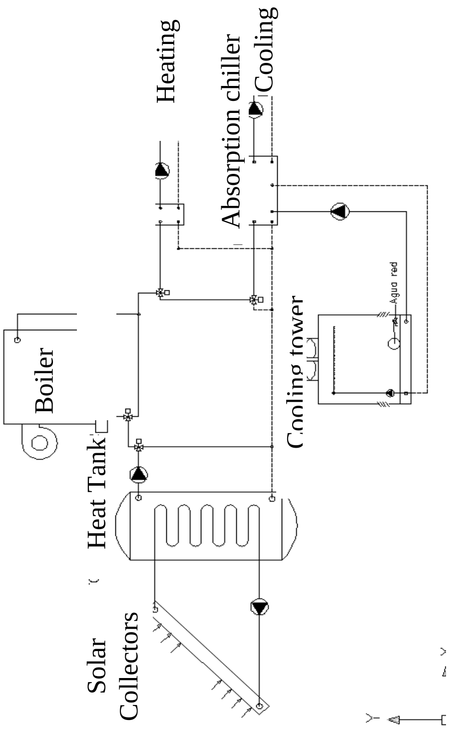

Fig.3 Scheme of solar system

5. Numerical simulacions

The aim is to compare a conventional system using heat pump in front of a solar air conditioning system.

The aim of the study is to analyze how economic influences variation of certain parameters in the solar air conditioning system, and reach optimal values of these parameters for the system studied.

NPV has been calculated at 20 years of installation, for different values of the parameters studied.

The parameters studied are the volume of the tank, the inlet temperature of the absorption chiller and area of collector depending on the meteorological conditions.

It has been chosen the TUR rate (Endesa web)

Tarifa TUR sin DH	€/kW
Tarifa TUR	0.114730

It have been selected the Isotherm Plus collector of Isofotón his cost is 581.73€/m^2 and Yazaki (70 Kw) absorption chiller.

A. *Economic results*

It will test the installation for different values of the parameters studied. The objectives of these tests is to know how the change affects the values of these parameters and to reach optimal values that make economic variables are as good as possible. Below are tables and graphs with the results for these trials, from which, it may reach conclusions.

In the economic study will compare the solar air conditioning system with a conventional air conditioning system. In addition, study how the variation of different parameters influencing the value of NPV.

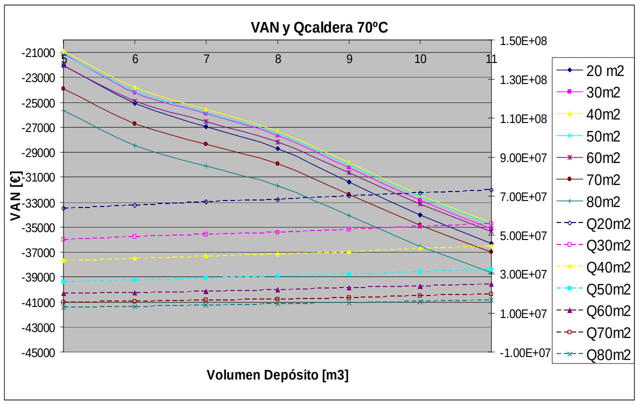

Fig. 4 VAN and anual heat supply by gas boiler. Input temperature absorption chiller 70ºC. Madrid

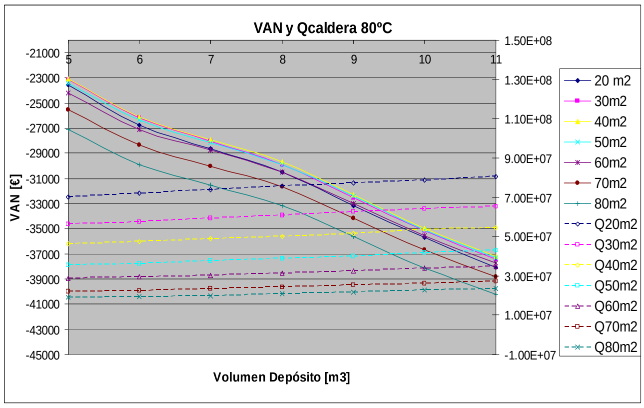

Fig. 5 VAN and anual heat supply by gas boiler. Input temperature absorption chiller 80ºC. Madrid

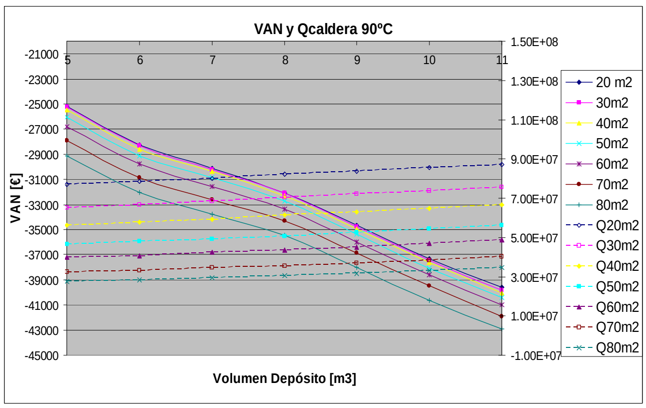

Fig. 6 VAN and anual heat supply by gas boiler. Input temperature absorption chiller 90ºC. Madrid

From these figures it can claim two main conclusions. One is that the NPV always decreases with increasing volume of the tank to the strip of volumes studied, the other conclusion is that the heat produced by the boiler annually, increases with increasing volume.

Therefore, one can conclude that the optimal size of the deposit for the range studied is 5 m3, both for economic reasons, for energy purposes.

1) Optimal parameters

The best option for the NPV are 40 m^2. As collectors have an area of 2.21 m^2, the value closest that can be reached is 39.78 m2, with 18 collector.

Inlet temperature which received the highest NPV in all cases is 70 ° C.

Finally tank volume which presents better NPV is 5m3.

B. Thermal Results

In this section, the interest will focus on the direct relationship between heat loss and temperature.

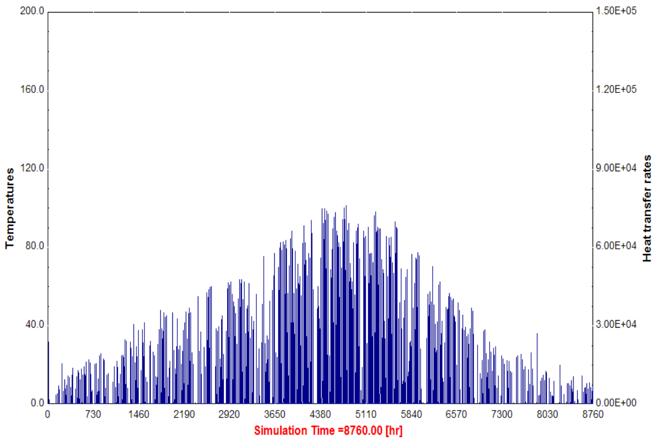

Fig. 7 Hourly heat supply by collectors in Madrid [kJ/h]

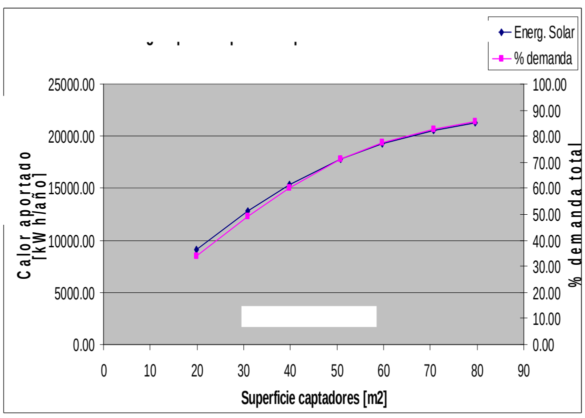

Fig. 8 Anual heat supply by collectors.Madrid

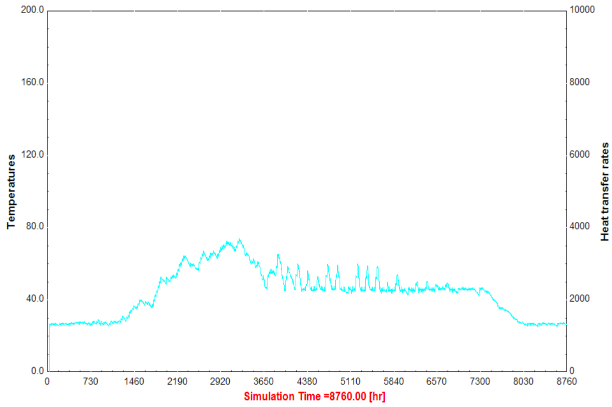

Fig. 9 Tank heat losses

6. Conclusions

The main contributions of the paper can be summarized as follows.

1.- Regarding the area of solar collectors, the slope of the solar supply curve decreases when the surface increases due to an increase in the average temperature of water in the collectors, what makes the performance to decrease.
2.-The increase of the volume of the storage tank provokes an increase in the yearly costs of gas boiler. This means that the increase caused by losses, due to the bigger contact surface with the outside is in this case more important than the increase of the capacity of heat storage linked to a bigger volume.
3.- Given the current technology and prices, for this kind of buildings (houses and offices) this investment is not finally recouped.

Acknowledgments

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