SIMULATION OF A SOLAR DRIVEN AIR CONDITIONING SYSTEM FOR A HOUSE IN DRY AND HOT CLIMATE OF ALGERIA

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ABSTRACT

Solar cooling technology is environmentally friendly and contributes to a significant decrease of the CO_2 emissions which cause the green house effect .Currently, most of the solar cooling systems commonly used are the hot water driven lithium bromide absorption chillers. According to the operating temperature of driving thermal source, single – effect Li Br/H_2O absorption chillers have the advantage of being powered by ordinary flat-plate or evacuated tubular solar collectors available in the market. The main objective of this work is to develop a computational model that allows the simulation of an hourly basis for an absorption refrigeration - single - effect used the LiBr/H_2O as solution working fluid- system assisted by solar energy and natural gas as auxiliary fuel coupled with the residential building located in the hot and dry climate of Algeria. This model will be developed using the dynamic simulation program TRNSYS, considering three specifics areas of work: determination of the cooling loads for a building, implementation of the computational model for the absorption refrigeration system and the parametric optimization of components, which will make possible an approach to optimal sizing of the solar absorption system. The results of the simulation of the absorption chiller indicate that an area of 28 m^2 of flat plat collectors with an inclination of 35° and 800 L for hot storage tank provides an annual solar fraction of 80% and a thermal performance coefficient COP of 0.73, getting to cover demand of air conditioning in a house of 120 m^2 located in Biskra (Algeria).

KEYWORDS: Solar Cooling Technology, Single-effect absorption chillers, Simulation, TRNSYS

1   INTRODUCTION

Summer air conditioning represents a growing market in buildings services world in both and residential buildings. Main reasons for the increasing energy demand for summer air-conditioning are the increased thermal loads, increased living standards and occupant comfort demands as well as building architectural characteristics and trends, like an increasing ratio of transparent to opaque surfaces in the building envelope to even the popular glass building [1].

This demand increase has various negative consequences:

- As most air- conditioning systems are supplied by electricity, this demand increase results in increases in both electricity consumption and the associated green house gas emissions.
- In addition, electrically powered vapour compression chiller technology uses CFC and HCFC refrigerants that cause pollution.

In this context, the introduction of other technologies that permit air conditioning using energy other than electricity is not only attractive, it is also necessary.

The application of solar energy in air- conditioning systems has several advantages, besides of offering a solution to the above mentioned difficulties, these include:

- The maximum cooling load coincides with the maximum available radiation.
- The equipment uses working fluids that are completely harmless, such as water and salt solutions.
- The technology enables solar heating installations to be usefully exploited even when there is no heating demand [2].

The current technologies in the market for cooling production, using solar thermal energy are: absorption machines, solid and liquid desiccant and solid adsorption. Cold production through absorption cycles has been traditionally considered one of the most desirable application for solar thermal energy [3].

In the 80 s of the last century, many activities on the development of solar energy systems for air conditioning application have been carried out, particularly in the United states and Japan. Important steps have been achieved in the development of components and systems, but finally the activities stopped mainly because of economies reasons. Recently, several new activities in this field have started and both research and demonstration projects are carried out in many countries and also in international co-operative projects such as the solar heating and cooling program of the International Energy Agency (IEA) .

2   THERMODYNAMIC LIMITS

In principle, there are many different ways to convert solar energy into cooling or air- conditioning processes, an overview is given in figure 1 [4].
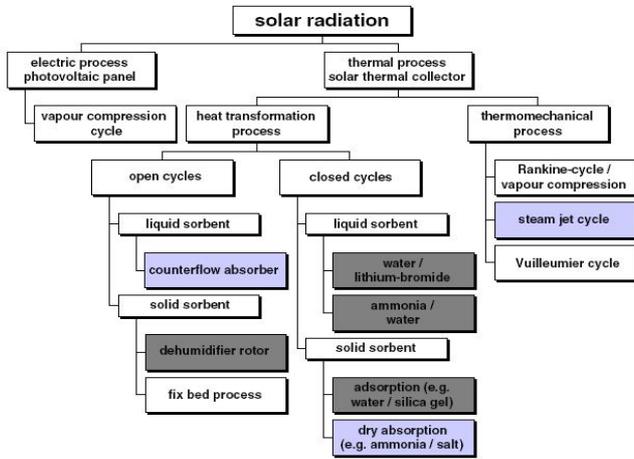

Figure 1: Overview on physical ways to convert solar radiation into cooling or air – conditioning. Processes market in dark grey: market available technologies which are used for solar assisted air – conditioning. Processes marked in light grey: technologies in status of pilot projects or system testing.

A refrigeration machine consumes energy to transfer heat from a source at a low temperature to a sink at a higher temperature.

In case of air-conditioning, the heat extracted from the low temperature source is the useful cooling.

As a result of the first law of thermodynamics, the flux of heat rejected at the intermediate level $\dot{\varphi}_{intermediate}$, is equal to the sum of the heat flux extracted from de low-temperature heat source; $\dot{\varphi}_{low}$, and the driving energy flux P_{drive} (In the case of thermally driven chillers) is a heat flux at a high temperature level $\dot{\varphi}_{high}$.

$$\dot{\varphi}_{intermediate} = \dot{\varphi}_{low} + P_{drive} \qquad 1$$

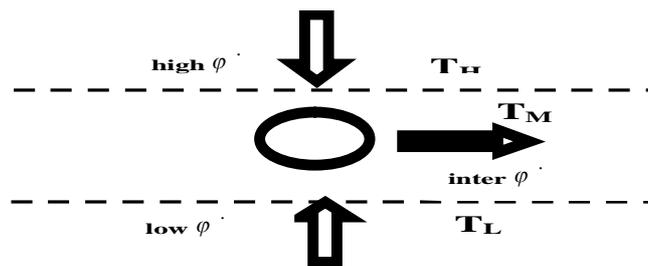Figure 2 shows the principle for the example of thermally driven chiller.

Figure 2: Basic thermodynamic scheme of a heat driven heat pump or chiller, respectively

A key figure to characterize the energy performance of a refrigeration machine is the coefficient of performance, COP. For thermally driven air – conditioning systems, the $COP_{thermal}$ which indicates the required heat input for the cold production can be defined as follows:

$$COP_{thermal} = \frac{\dot{\varphi}_{low}}{\dot{\varphi}_{high}} \qquad 2$$

$$COP_{thermal} = \frac{\text{Heat flux extracted at low temperatu re level}}{\text{Driving heat flux supplied to cooling equipement}}$$

For a conventional, electrically driven vapour compression chiller, the COP_{conv} is defined as the required electricity input for production of cooling energy :

$$COP_{conv} = \frac{\dot{\varphi}_{low}}{\dot{\varphi}_{drive}} \qquad 3$$

$$COP_{conv} = \frac{\text{Heat flux extracted at low temperatu re level}}{\text{Electrical power supplied to the chiller}}$$

Lead to an expression for the maximum possible coefficient of performance, COP_{ideal} :

$$COP_{ideal} = \frac{T_L}{T_H} \cdot \frac{T_H - T_M}{T_M - T_L} \qquad 4$$

Where T_L is the temperature of the cold source, T_H is the temperature of the driving heat source and T_M is the intermediate temperature level at which the heat is rejected to a heat sink (in general environmental air). The COP_{ideal} is shown in figure 3 together with real COP values of thermally driven chillers available on the market [1]
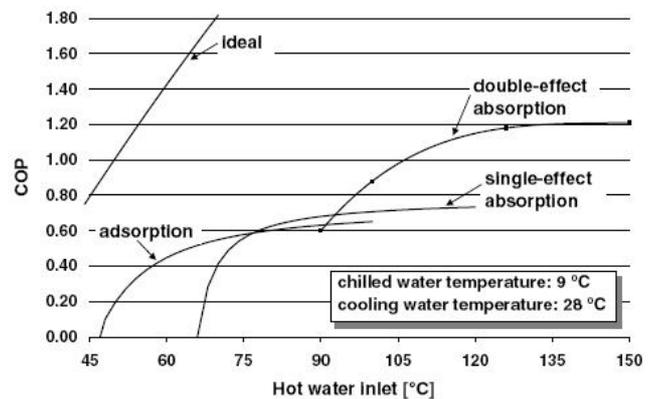

Figure 3: COP-curves of sorption hillers and the upper thermodynamic limit (ideal) according to Eq.(2.4).

The efficiency of a solar assisted air conditioning system is highly dependent on the temperature levels in the thermally driven chiller circuits:

- The higher the temperature of the driving heat, the higher the COP of the chiller but the lower the efficiency of the collector field.
- The lower the temperature of the rejected heat, the higher the COP of the chiller but the bigger the size of the cooling tower.

- The higher the temperature of the cooling output, the higher the COP.

3 ABSORPTION COOLING TECHNOLOGIES

Absorption cycles are based on the fact, that the boiling point of a mixture is higher than the corresponding boiling point of a pure liquid. In an absorption refrigeration system, the refrigerant evaporates in the evaporator, thereby extracting heat from a low– temperature heat source. This results is the useful cooling effect, the refrigerant vapour flows from the evaporator to the absorber, where it is absorbed in a concentrated solution. Latent heat of condensation and mixing heat must be extracted by a cooling medium, so the absorber is usually water-cooled using a cooling tower to keep the process going.

The diluted solution is pumped to the components connected to the driving heat source (i.e, generator or desorber), where is heated above its boiling temperature, so that refrigerant vapour is released at high pressure. The concentrated solution flows back to the absorber, the desorbed refrigerant condenses in the condenser, where by heat is rejected at an intermediate temperature level. The condenser is usually water-cooled using a cooling tower to reject the "waste heat ".

The pressure of the refrigerant condensate is reduced and the refrigerant flows to the evaporator through an expansion valve. A schematic drawing of a basic absorption is shown in figure 4.
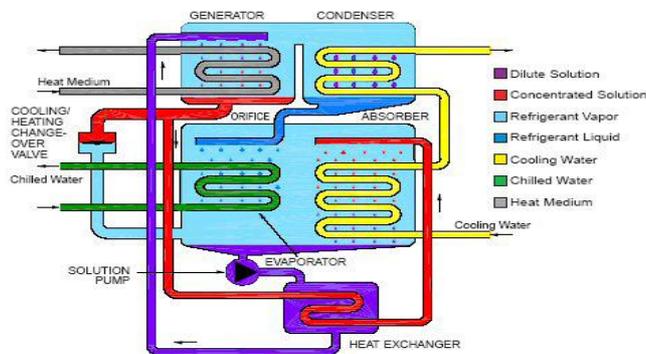

Figure 4: Scheme of absorption machine

Figure 5: Small size single effect absorption cooling machine
.Source: YAZAKI

Manufacturer	Cooling load , type
Broad Air	20 KW LiBr / H_2O single and double effect
Colibri /Stork	100 KW NH_3 / H_2O single effect
EAW	15 KW LiBr / H_2O single effect
Robur Corporation	17 kw-88 KW LiBr / H_2O single effect
Yazaki	35 KW LiBr / H_2O single effect
York	420 KW LiBr / H_2O double effect

The heat required for step three can be supplied, for instance, by direct combustion of fossil fuels, by waste heat or solar collectors. Depending on the required cooling effect, the working pairs for absorption chillers is employed; for a temperature of the low temperature heat source higher than 5°C; for example used for air-conditioning a water / lithium bromide (Li Br) pair absorption machine, is most frecently used, which must be water-cooled.

A review of the research of the state-of-the-art solar sorption (absorption and adsorption) refrigeration technologies was presented by Fan al Ziegler [5] has discussed different issues in increasing the efficiency of open and closed sorption systems, and making solid and liquid sorption systems economically competitive. For sorption technology to be ecologically competitive, highly efficient systems are required to cope with the increasing efficiency of compression systems and power plants.

3.1 Solar – powered single effect absorption systems

For solar- assisted air-conditioning systems (Figure 6) with common solar collectors, single-effect absorption chillers are the most commonly used systems, because they require a relatively low temperature heat input. The term 'single effect' refers to the fact that the supplied heat is used once by a single generator.
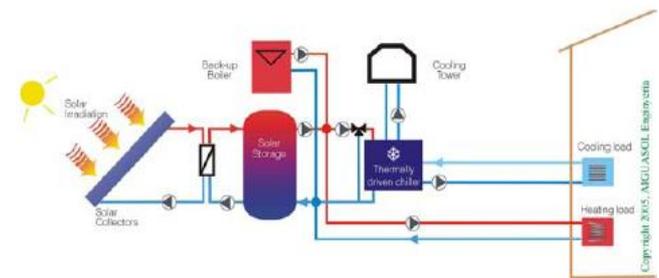

Figure 6: Solar–assisted with thermally driven chiller system with back-up heat source

Thermodynamic restrictions in the system dictate that the cooling capacity for ideal and real systems is always less than the heat input. The heat input to drive the generator, φ_{high} must supply both the required heat of evaporation, r,

that is required to vaporize the refrigerant out of the diluted water –lithium bromide solution and the heat of solution, l. Hence, the upper limit of the coefficient of performance for an ideal single-effect cycle of an absorption chiller is defined as follows:

$$COP_{thermal,max} = \frac{\dot{\varphi}_{low}}{\dot{\varphi}_{high}} = \frac{r}{r+l} \qquad 5$$

Typical COP' s for large single-effect machines lie in the range of 0.7 to 0.8.

Table 1: Examples of commercially available absorption chillers suitable for solar-assisted air-conditioning (only smallest available size included).[Henning .07]

Manufacturer	Cooling power,type ·	Driving T(°C)	Typical operation conditions, rated COP(if available)
Broad Air	20kw single and double effect	No data	No data
Colibri /stork	100kw NH₃/H₂O single effect	>90	$T_{cooling\ water}$ 27/32°C , $T_{chilled\ water} < 2°C$: COP - 0.64
Cooling Tec	70KW R-134a/organic materials single effect	70 – 145	Example : T_{drive} 90°C , $T_{cooling\ water}$ 27°C , $T_{chilled\ water}$ 2°C : COP - 0.55
Dunham-Bush	327 KW single effect	Steam ,112	chilled water 51m³/h, cooling water105m³/h, steam777kg/h
EAW	15 KW single effect	75 – 95	Example : T_{drive} 85°C , $T_{cooling\ water}$ 30°C , $T_{chilled\ water}$ 12°C ;COP - 0.70, hot/chilled water 2m³/h, cooling water 5m³/h
Sanyo	105 KW single effect	85 – 95	Hot water 26.5 m³/h, chilled water 8°C, cooling water 29.4°C
Trane	394 KW reversible single effect	> 100	No data
Yazaki	35 KW single effect	80 – 100	chilled water 6 m³/h, cooling water14.5m³/h
York	420 KW double effect	>116	chilled water 65 m³/h, cooling water 98 m³/h

· All water /lithium-bromide unless otherwise indicated .Driving source :steam or hot water

3.2 Experimental investigations

Although there were some solar absorption cooling systems in large capacities up to several hundred kilowatts. The experimental investigations were mainly based upon medium and small-sized solar cooling systems. Usually, the cooling capacity and COP of solar cooling systems were tested under pratical operating conditions.

Rosiek and Batlles [6] reported the solar –powered single-effect absorption cooling system installed in the solar energy research center of Spain.

According to the calculation, the heating and cooling demand during the whole year were 8124 KWh and 13255 KWh, respectively. The flat plate solar collectors with the area of 160m² were used to meet the energy demands either for heating in winter or cooling in summer. For covering the cooling demand, a single –effect absorption chiller with the cooling capacity of 70 KW was chosen. During one year of operation, it could be seen that the solar collectors were able to provide sufficient energy to supply the absorption chiller during the summer mode and sufficient to cover the whole heating demand. The average values of COP and the cooling capacity were calculated for summer months, obtaining values of the order of 0.6 and 40KW, respectively [3].

In Task 25 "solar assisted air conditioning of building " a project that has been carried out of the framework of the solar Heating & cooling program of the International Energy Agency (IEA) 11 plants in six countries were monitored-for example, in Spain, the project is "stagnation –proof transparently insulated flat plate solar collector ((STATIC) Air cooled H₂O/Li Br absorption chiller with a low capacity (ACABMA) [7], flat plate collectors with honey comb transparent insulation cover as a low cost alternative for evacuated tube and CPC collectors for temperatures of 80– 160°C.

A SARANTIS cosmetics factory at Inofita Viotas, Greece, is the largest European solar cooling installation, the facility includes a total area of 2700 m² flat –plate solar collectors, coupled with two absorption chillers (total cooling power 700 KW) for meeting 40 % of the total cooling load of the factory (22000 m²). The installation was completed in 1999[4].

Praene et al [8] presented a solar – powered 30 KW LiBr/H₂O single-effect absorption cooling system which was designed and installed at institute universitaire technologique of Saint Pierre. It was reported that solar loop could produce hot water to fire the absorption

chiller from 8:00 AM to 5:00 PM. According to the first field test, the system was sufficient thermal comfort with the mean air temperature inside the classrooms of about 25°C.

The existing experimental results showed that solar-powered single-effect absorption cooling systems were capable of working in the driving temperature range of 65-100°C [3]. Generally, the system COP of about 0.6 could be obtained under the design condition.

3.3 Theoretical analysis and simulation

The main components of a solar absorption cooling system are the solar field, the absorption chiller and the heat storage water tank. Such research works were carried out mainly by theoretical analysis and simulation with the aid of TRNSYS program.

Balghouthi et al [9] presented a research project aiming at assessing the feasibility of solar– powered absorption cooling technology under Tunisian conditions, the system was modeled using the TRNSYS and EES programs with meteorological year data file containing the weather parameters of Tunis.

The optimized system for a typical building of 150 m^2 was composed of a LiBr /H$_2$O absorption chiller of a capacity of 11 KW, a 30 m^2 flat – plate collector area titled 35 ° from the horizontal and 0.8 m^3 hot water storage tank.

Laoufi et al [10] reported the results of optimization process of the absorption on refrigeration system assisted by solar energy under south Algerian conditions, indicate that the area of 12 m^2 of flat-plate collectors with an inclination of 23° and 0.5 m^3 storage tank provides, getting to cover the demand of air conditioning in a house of 20 m^2.

Vidal et al [11] simulated and optimized a Li Br /H$_2$O solar absorption refrigeration system considering as study region the city of Santiago. The model will be developed using the dynamic simulation program TRNSYS, the result indicate that an area of 110 m^2 of flat-plate collectors with an inclination of 33° and 7 m^3 storage tank provides an annual solar fraction of 70%, getting to cover the demand of air conditioning in a house of 145 m^2.

Joudi and Abdul – Ghafour [12] developed an integrated program for the complete simulation of a solar cooling system with a Li Br/H$_2$O absorption chiller. The results obtained from the simulation were used to develop a general design procedure for solar cooling systems, presented in a graphical from called the cooling f-chart using this design chart could simplify the designer 's task for predicting the long term cooling energy supplied from a solar collector array serving an absorption chilled water system.

The coupling of the main components of a solar cooling system is determined by the cooling demand time series, solar resource availability, climatic conditions, component cost and component performance characteristics. The optimum design should be based upon simulation results according to pratical projects. Mazlouni et al [13] simulated a single-effect absorption cooling system designed to supply the cooling load of a typical house in Ahwaz, Iran in all hot climate conditions where maximum cooling load is about 17.5 KW. Solar energy was absorbed by a horizontal N-S parabolic trough collector and stored in an insulated thermal storage tank. The results indicated that the maximum required collector area is about 58 m2 which was supply cooling loads for the sunshine hours of the design day.

The main components of a solar absorption cooling system are the solar field, the absorption chiller and the heat storage water tank.

The overall system performances depend on the coupling of these three components. Such research works were carried out mainly by theoretical analysis and simulation with the aid of TRNSYS program.

Florides et al [14] modeled a solar-powered absorption cooling system of a typical house in Cyprus using TRNSYS simulation program and the weather conditions of Nicosia, Cyprus. The final optimum system consisted of a 15m2 compound parabolic collector tilted at 30° from the horizontal and a 600 L hot water storage tank.

Assilzadeh et al [15] presented a solar cooling system that had been designed for Malaysia and similar tropical regions using evacuated tube solar collectors and LiBr/ H2O absorption unit. The modeling and simulation of the solar absorption cooling system was carried out using TRNSYS program. The typical meteorological year file containing the weather parameters for Malaysia was used to simulate the system. The results showed that a 0.8 m^3 hot water storage tank was essential in order to achieve continuous operation and increase the reliability of the system. The optimum system for Malaysia's climate for a 3.5 KW system consisted of 35 m2 evaluated tube solar collectors tilted at 20°.

In addition to TRNSYS analysis, Atmaca et al[16] developed a computer program for a solar absorption cooling system to simulate various cycle configurations and solar energy parameters for Antalya, Turkey.

It was shown that the solar collector area of 50 m2; a 3750 kg storage tank mass seemed to be the best choice.

Ward and Lof [17] described a first integrated system which provides heating and cooling to a building by use of solar energy. The plant had been installed in a residential building at Colorado State University. It was designed to cover 60% of the heating and cooling load of the building.

Ward et al [18] reported about the possibility to improve the average coefficient of performance (COP) of the cooling system by the use of a cold water storage.

Bong et al[19] describes a solar-powered 7 KW absorption chiller in Singapore. The system included heat pipe collectors with a total area of 32 m2, an auxiliary heater, a hot water storage tank, and a 17.5 KW cooling tower. The overall average cooling power provided was 4 KW, COP of 0.58 and a solar heat fraction of 39 %, which means 60% of the driving heat work was provided by the auxiliary heater.

Al- Karaghouli et al[20] reported the operation results of a solar cooling system which was installed at the solar Energy Research Center in Iraq. The system is equipped with two absorption chillers with a cold capacity of 235 KWth for each,1577 m^2 evacuated tube collectors and 2 thermal storage tanks of 15 m^3. They reported that the daily average solar collection efficiency is 0.49, the COP of the chiller is 0.618 and the solar heating fraction is 60.4 %.

Yeung et al[21] reports about a solar driven absorption

chiller with a cold capacity of 4.7 KWth at the University of Hong Kong. The system included flat collectors with a total area of 38.2 m^2 and 2.75 m^3 hot water storage tank. The collector efficiency is estimated with 0.375, the annual system efficiency is 0.078 and the average solar fraction is 55%.

Ali et al [22] have described the performance assessment of an integrated cooling plant with combined free cooling and solar-powered single-effect lithium bromide-water absorption chiller of 35.17 KW cooling that includes vacuum tube collectors with gross and net areas of 108 m^2 and 72 m^{2}respectively, a cold water storage capacity of 1.5 m^3, a hot water storage capacity of 6.8m^2 and a 134 KW cooling tower. The plant provides air-conditioning for a floor space of 270 m^2.

Tierney [23] in his simulations on the comparison of energy saving by a solar assisted cooling system with gas firing has obtained 39 % for a combination of a single-effect chiller and trough collector; 32 % for a double-effect chiller and flat-plate collector; 86% for a double-effect chiller and trough collector.

Tsilingiris [24] presented a theoretical microcomputer model to investigate the operational behavior of a simple design solar LiBr-H2O absorption cooling system with 7 KW cooling load capacity for small residential applications in Greece. Assuming fixed condenser and chilled water temperatures of 30 and 8°c, respectively, the chiller capacity and COP according to manufacturer's data are given as a function of generator temperature. The results showed that the yearly solar fraction is proportional to the collector area, and it would reach values up to 45% for double glazed flat-plate collectors of 50 m^2 areas with a fixed tilt angle of 20° facing south and 1000 l storage tank capacity. It was concluded that even at the present costs of fossil fuels, electrical energy and mechanical components, solar air-conditioning is an economically marginal application when not combined with solar heating.

Ghaddar et al [25] modeled and simulated a solar absorption system for a typical house in Beirut. The absorption cycle was simulated by a thermodynamic model. Hourly values of the direct and diffuse components of solar radiation incident on the collectors and the values of ambient temperature, wind speed and direction were derived directly from actual hourly measured weather data files. The delivery water temperature to the generator was above 65° c and the temperature in the storage tank was not allowed exceed 95°C. The load required for the generator was calculated based on an evaporator temperature of 10°c and condenser temperature equal to the dew point temperature of the ambient air. The results showed that for each ton of refrigeration, it is required to have a minimum flat-plate collector area of 23.3 m^2 with an optimal water storage tank capacity of ranging from 1000 to 1500 l for the system to operate solely on solar energy for about 7 h a day. The economic analysis showed that the solar cooling system is marginally competitive only when it is combined with domestic water heating.

4 DESCRIPTION OF THE COMPUTATIONAL SIMULATION

Computer simulation software has become very attractive to researchers because of its usefulness in predicting system behavior.

Reliable simulation is a most when dealing with solar cooling systems as there is not a standard layout for this application and there is a lack of operable experimental cooling facilities with accurate data. In recent years TRNSYS has become to be the most reliable modeling and simulation program oriented towards solar application used by researchers.

TRNSYS, an acronym for transient simulation, permits to evaluate the behavior of a solar application in a quasi-steady state analysis improving the accuracy in describing applications that are characterized by solar energy's intermittent behavior.

4.1 The TRNSYS interface

The TRNSYS interface interacts with the user as a graphic programming tool. This means that no previous knowledge of a programming language is necessary to create and run a simulation, althrough TRNSYS allows modifying its component models with several common programming languages. Component models refer to subroutines that the TRNSYS program libraries incorporate in its standard version, each subroutine models a specific component.

A broad variety of thermal energy systems, like solar thermal collectors, TES, heat exchangers, single and double effect absorption chiller, etc, constitutes the libraries and many of the components used in solar cooling facilities are availabel. The component models are characterized by their specific inputs and outputs, thus outputs of a specific component can be linked as input to others, building the desired virtual configuration.
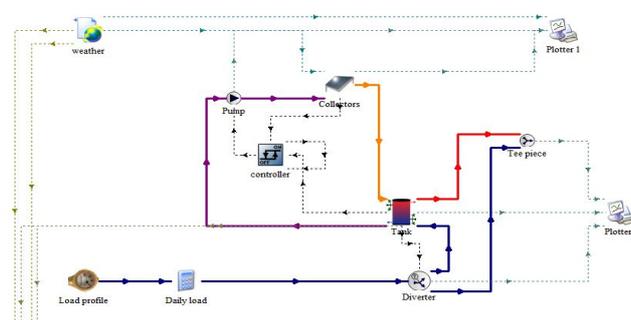

Figure 7: The TRNSYS interface : model of the solar hot water

In order to run a simulation of a solar facility of any kind, weather data is indispensable, it is suggested to have a database for a Typical Meteorological Year (TMY) in the locality under study. In this work, the climate database was built using the software Meteonorm of Africa exactly

Biskra (latitude °N34.85, longitude °E 5. 72, altitude (m) 87).

4.2 Modelling of air conditioning demand

The house under study is located in the surroundings of the Biskra (south east of Algeria) with a 120 m^2 area.

For a proper determination of the refrigeration loads in the building under study, it is a vital requirement an appropriate consideration of the load components in the space will be conditioned.

For this, results imperative to consider the following parameters; the building orientation, its dimensions and materials besides the configuration of doors and windows contribute mainly to determine the amount of energy that enters or leave in an external way to the building (external loads).

In the last version of TRNSYS (version 17.1)[26] we found **Type 56** (multi-zone building) Component from a Google sketchup model and will create an executable TRNSYS simulation that can be run directly from Google Sketchup, thereby combining the power of the TRNSYS simulation environment with the simplicity and ease of use of Google sketchup.
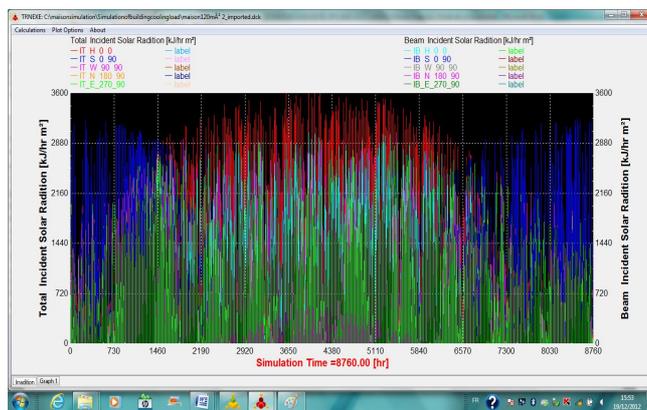

Figure 8 : Total and Beam incident solar radiation [Kj/ hr.m²]on the surface of building under study
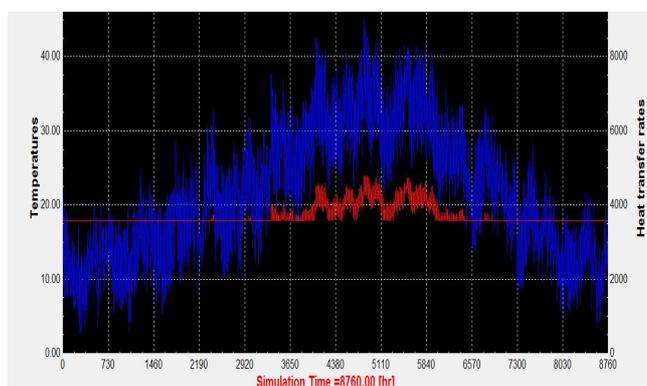

Figure 9: Variation of temperatures vers hour: ambiant temperature (blue), temperature of the zone (red)

5 SIMULATION METHODOLOGY

Regarding TRNSYS models, novel types were created for absorption chillers, using COP values from manufacturers' data (not just COP $_{maxi}$ but COP$_{(T)}$). The model is able to run for a whole year (365 days) according to control rules.

For building simulation, **type 56**, this component models the thermal behavior of building having multiple thermal zones. The building description is ready by this component from a set of external files having the extension B17 (bui in version 16 of TRNSYS).

The files can be generated based on user supplied information by running the preprocessor program called TRNBuild **type 1b** allows the simulation of a flat –plate collector. For hot thermal storage, a stratified liquid storage tank, with two inlet and two outlet flows (**type 60**). For cold thermal storage **type 60 f** is used. Several data files of absorption chillers of single-effect employing **Li Br – H$_2$O** solution as working fluid, (type **107**) according to Yazaki chiller WFC SH10.

Other types used were: **Type 15-2-TMY2**, **type 3b** for simulation of pumps.

6 ANALYSIS AND DISCUSSION OF RESULTS

The case study considered in this work corresponds to a solar absorption refrigeration system serving a demand for air conditioning under dry and hot climate of the Biskra (south of Algeria).

From the simulation done with the TRNbuild (Type 56) of TRNSYS to determine the demand for air conditioning in the house under study, we obtained results that indicate that this demand starts from April to September, with critical periods for the months of June, July and August in which occurs the maximum load of 17KW.

Multiple simulations are performed with TRNSYS model to evaluate the most relevant factors that make possible an idea of the optimal size of solar absorption refrigeration system and analyze the effects of key variables that influence its performance. Among the factors investigated are the effect of the area and slope of solar collector, thermal reservoir volume, the gain of useful energy and consumption of auxiliary energy.

An auxiliary heater with natural gas as fuel as a back -up, which has a maximum capacity of 20 KW. Figure 10 shown the influence of area of solar collector on the auxiliary energy of the system. The range of analysis for the collection area variable covers from 5m² to 40 m², with variations of 5 m² and its observed that an increase in the collection area leads to a decrease in the solar energy requirements on the auxiliary heater. The effect is amplified when using a solar collector of higher performance. However, the process of optimizing the solar collection area requires a thermo economic analysis.
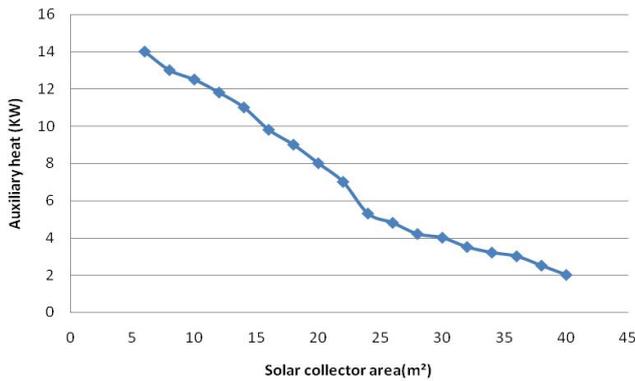
Figure 10:Effect of the collector area on the auxiliary heat of the system

The gain of useful heat in solar collector for different area of solar collector, is shown in figure 11. This shows that the gain of useful energy collector increases with the area collector increases.
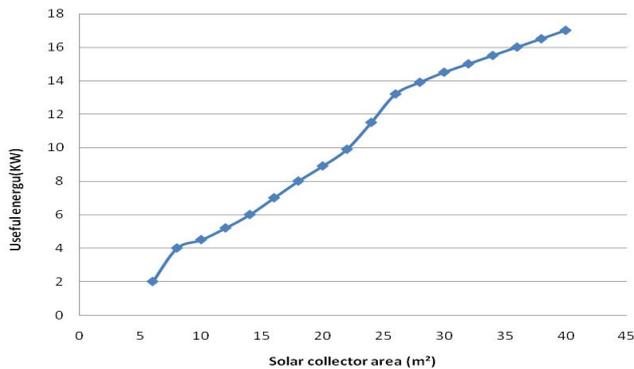

Figure11 : Effect of the collector area on the gain of useful energy

The effect of the volume size of the storage tank on the consumption of auxiliary energy is investigate. The results of this simulation are shown in figure 12, where we can see that the auxiliary energy used reaches a minimum value for a reservoir volume of 0.8 m^3
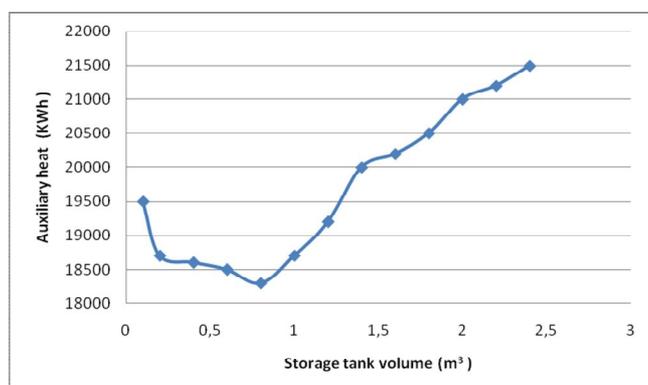

Figure 12: Effect of tank volume on the consumption of auxiliary energy of the system

Another parameter that effects system performance, is the angle of inclination of the collecting surface with respect to the horizontal. In figure 13, it is shown the influence of the incination of the collector plate on the useful energy gain, which is maximized for an angle of 35°.
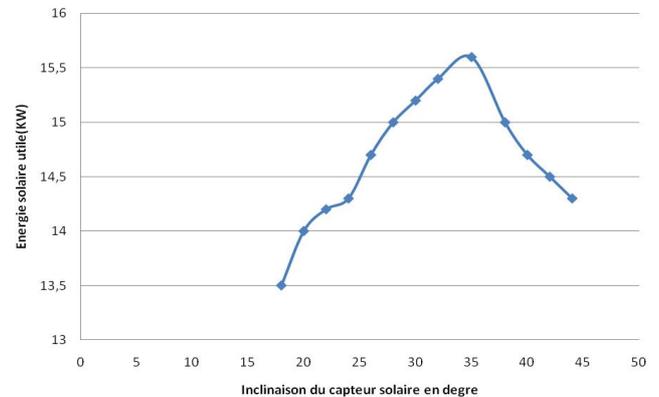

Figure 13: Effect of the inclination angle of the collector on the useful energy of the system

7   CONCLUSION

Solar cooling systems can be used, either as stand –alone systems or with conventional air – conditioning systems, to improve the indoor air quality of al types of building. The main advantages of solar cooling systems concern the reduction of peak loads for electricity utilities, the use zero depletion impact refrigerants, the decreased primary energy consumption and decreased global warming impact.

Several thermally driven air-conditioning technologies are market available by today which enable the use of solar thermal energy for this application.

Solar – assisted air conditioning can lead to remarkable primary energy savings, if the systems are properly designed. Pre-condition to achieve primary energy savings is a sufficient collector size and suitable size of energy storage in the system.

In the modeling of the demand for air conditioning was used the TRNbuild module of TRNSYS, which allows to simulate in a dynamic way the air conditioning requirements for the building. The results of the simulation of an absorption chiller at single effect of 10 KW assisted by solar with the thermal COP is 0.73, indicate that with an area of 28 m^2 of flat plate collectors with an inclination of 35° and 800L of water hot storage tank is achieved to cover the demand of air conditioning of the house of 120m^2 located in Biskra.

Finally, the model developed can be used to perform a thermo economic optimization of the system .Additionally, different alternatives to considered in this investigation can be evaluated: different sizes of absorption chiller, variable flow pumps, different climates of Algeria.

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