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Optimization of Solar Cooling Systems with Simulation Modeling

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Abstract

Rising energy costs and environmental problems, also the limited resources of fossil fuels, have forced humans to use renewable energy. One of the systems that are commonly used is the cooling system, by means of solar energy. Since these models have a wide variety of effective variables, such as the temperature, latitude, the length of the day, also due to the nonlinear relationship between the variables, conventional modeling methods are inefficient. Therefore regarding to the extensive capabilities of simulation models in modeling a wide range of variables with complex and nonlinear relationship, in this study with the approach of simulating solar systems, an effective survey in the field of economic and efficiency of such systems, is presented.

Keywords: Solar Energy, Simulation-Optimization, Solar Cooling Systems, Feasibility Study, Arena Software.

1. Introduction

Energy price fluctuations, desire to reduce fuel consumption and energy costs, also storing fossil fuels for applications more than just burning, furthermore the necessity of reducing emissions and fuel consumption in the last decade, are prominent reasons for altering attitudes toward the energy utilization .In recent years with the introduction of targeted subsidies in Iran, lowering the costs has become notable .Whereas accessing to clean and renewable energy is important, because of both economic and environmental aspects. Therefore renewable energies can be considered as an alternative for energy supply. Among renewable energy resources, the solar energy is one, which seems to be a good choice for energy supply.

In general, on residential and commercial applications, the demand for refrigeration and air conditioning is covered by conventional energy, which causes a considerable overload in the electric grid distribution [1].In Iran, about 40% of total annual energy consumption is related to the building sector, and it has an important share in energy demand [2].One solution to avoid high consumption of heat and cold supply systems, is replacing conventional systems with a more efficient one. However, the cost of implementing a more efficient system is higher but definitely overpaid will be returned during the first few years, through energy savings.

The amount of solar energy received by the Earth per 15 minutes is equal to the amount of energy used in all countries. Iran as a Middle Eastern country has recently begun to use renewable energies. Solar

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energy, because of its availability and large number of sunny days in this country, is mostly concentrated [2].

The use of solar energy in building is an important issue because of its contribution in the reduction of the fossil fuel consumption and the harmful emissions of the pollutants into the environment [3].In Iran, solar energy is mostly used for projects such as designing and building a solar shower, solar water heating installation and solar parks and no activities are done to construct solar chillers [2]. Using solar energy for heating and cooling of buildings is a new idea that was raised in 1930 and reached considerable progresses in less than a decade [4].

An international scheme, Solar Heating and Cooling Program has been advocated by the International Energy Agency since 1976 and a variety of publications for design, installations, operation and maintenance of the solar energy systems to heat, cool, power and light buildings are currently available to the building actioners [5].

Due to Iran's hot and dry climate, most days are warm and sunny, make it essential to find a suitable source of energy to supply cool weather, and therefore solar energy seems to be a good one, because of good suns radiation received in whole country.

Conventional compression evaporative cooling systems that work by electricity have been applied, for nearly a century, in various sectors such as industry, transportation and domestic uses. In the recent years, feasible technology to utilize solar energy for air-conditioning and refrigeration is available, and different system designs and configurations are being developed [4]. Among the heating assistance technologies, the performance of the so called absorption cooling systems is based on the cooling, which hot water supplies from the solar absorptions. Basically this system`s operation, largely deals with the availability of solar radiation.

The absorption chiller was invented in 1860 by Ferdinand Frenchman and was registered in the United States. Solar absorption chiller was designed in 1974 by Yazaky Japanese Company and since then using this type of absorption chiller has been improved. Considering the high cost of implementing solar systems, regarding to the extensive capabilities of simulation models in modeling a wide range of variables with complex and nonlinear relationship and also by noticing Iran's great potential (due to geographical location and exposure of less than 40 degrees south latitude), the goal of this study is to present an effective survey in the field of economic and efficiency of such systems.

2. Absorption Cooling System Description

We have two types of cooling systems, condensation cooling and absorption cooling. In the Condensation cooling system, there is a dense that uses a lot of energy to compress the fluid [6].

While in absorption cooling systems, only pumps use electrical energy and there are absorbent and generator instead of compressor [6].

There are generally two types of chillers, condensation chiller (existing conventional systems) and the absorption chiller, and also Absorption chillers are divided into two categories:

- Absorption chiller with a solid adsorbent: Silicagel and water
- Absorption chiller with a liquid absorbent, lithium bromide and water, ammonia and water [7].

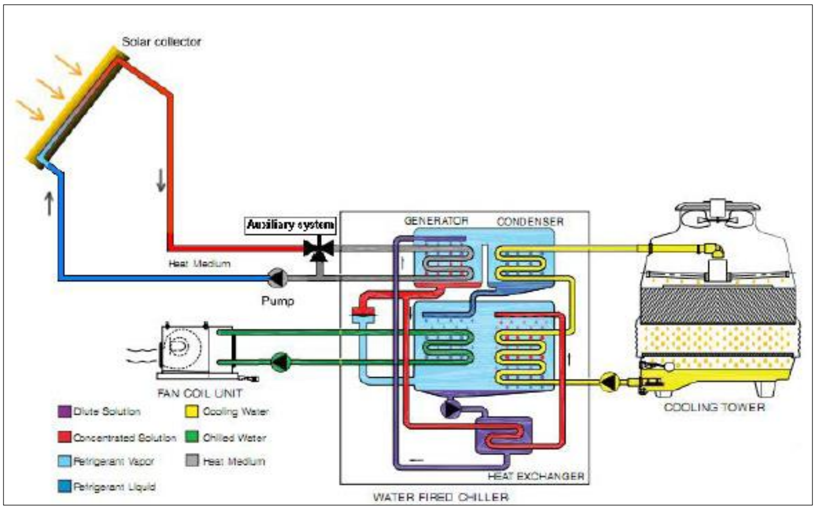

Figure 1. Absorption refrigeration system assisted by solar energy and natural gas [6]

The main components of this system are: Flat Plate Solar Collectors, a Hot Water Storage Tank, Absorption Chiller, a Cooling Tower and an Auxiliary Heater.

It is necessary to be mentioned that each of these systems are needed to be supplied by an auxiliary fuel, in order to compensate shortage of the sun`s radiation in cloudy or dusty days.

In figure 1 an absorption refrigeration system assisted by solar energy and natural, is shown. The operation of the system begins storing on a thermal reservoir of water the energy received by the solar collectors. Then, hot water accumulated in the tank is supplied to the generator of the absorption chiller to produce the separation between the absorbent and refrigerant which is achieved through an endothermic process mixing Lithium Bromide and water. The generator of absorption chiller requires a minimum inlet temperature of hot water to avoid the crystallization phenomenon. When solar energy is not able to raise the water temperature up to that point, the auxiliary heater provides the energy deficit for the correct operation of the chiller. After that, the refrigerant (water) evaporates and passes directly to the condenser, leaving in the generator a strong solution of absorbent, which is deposited then in the absorber [8].

In the condenser, the refrigerant vapor is cooled down by the addition of cooling water coils that comes from a cooling tower outside the system and then deposited in the evaporator, passing through an expansion valve to lower its temperature further.

Once in the evaporator, the refrigerant evaporates at very low temperatures because the device is close to vacuum pressure, extracting heat from an external liquid circuit in order to produce air conditioning. In the absorber, due to the enormous affinity absorbent-refrigerant, the strong solution of absorbent attracts the refrigerant vapor from the evaporator, turning back into a weak solution, which is then pumped to the generator to start the cycle again.

Here in figure 2 the Energy Path Diagram through the system is drawn to obviously determine the energy cycles through the system, to be helpful in simulation modeling.

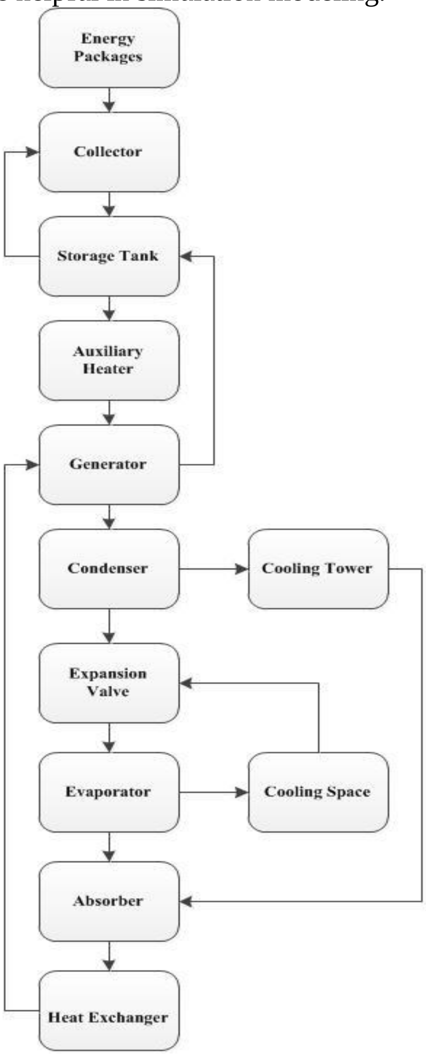

Figure 2. The Energy Path Diagram through the system

3. Nonlinear Equations for Modeling Solar Absorption Chiller

Here there are some formulas used in calculating absorption chiller thermal Balance [6];

$$Qg + Qe = Qc \tag{1}$$

Table 1. Necessary information to write papers

Description	Symbol
Generator Power (kw)	Qg
Heat absorbed by the evaporator (kw)	Qe
Heat absorbed by the cooling tower (kw)	Qc

The best collector slope is equal to the latitude of the chiller installation [6].

(For simulation) the amount of radiation in a month on the optimum collector slope is obtained from the following equation:

$$\overline{H}_{\mathrm{t}} = \overline{H}_b \overline{\mathrm{R}}_{\mathrm{b}} + \overline{H}_d \left(\frac{1+\cos\beta}{2}\right) + \overline{H}\,\rho_{\mathrm{g}} \left(\frac{1-\cos\beta}{2}\right) \tag{2}$$

Table 2. Necessary information to write papers

Description	Symbol	Unit
The total radiation Per month, on the Collector surface, with optimization Gradient to the collector area	$\overline{H}_{\mathrm{t}}$	$Mj/\mathrm{m^2.Day}$
The Ratio of Monthly radiation on inclined surface angel, to The Monthly radiation angle on a horizontal surface	$\overline{\mathrm{R}}_{\mathrm{b}}$	-
collector slope	β	degree
The grounds Reflection coefficient	ρ_{g}	-
Monthly radiation directly to the Horizon	$\overline{H}_b$	$Mj/\mathrm{m^2.Day}$
Monthly radiation scattered to the horizon	$\overline{H}_d$	$Mj/\mathrm{m^2.Day}$
Monthly radiation on a horizontal surface	$\overline{H}$	$Mj/\mathrm{m^2.Day}$

As shown above, there are complex and nonlinear relationships for determining the relations between factors which are prominent in solar absorption chiller thermal Balance. Therefore the importance of replacing these computational relations with a user friendly model which can easily decide on this field is obvious.

4. Simulation Process by Arena software

In this research, by means of simulation- optimization methods, these objectives are followed:

- Cost Reduction
- Efficiency increasing

Along these objectives, certain characteristics are fixed and unchangeable (or in other words, they follow a specific distribution function):

- The amount of solar radiation energy per city and its distribution
- The number of hours of sunny hours per city and its distribution
- The number of sunny days per city and its distribution function
- Space requirements (which is limited in any building)
- Limited budget for implementation (this case and previous one is different for each consumer and has a constant value) and ...

Purposes such as determining the optimal number of collector, cosidering sunshine and temperature in each city, increasing efficiency and minimizing operating costs, will be followed. In oreder to accomplish all these goals, simulation – optimization is a suitable tool. Following these objectives, the optimal number of collectors, efficiency, costs and profits are determined.

In order to simulate the system, data should be collected from sources such as Global meteorological database and local databases in this field. Important data for simulation are: the weather temperature, the number of sunny hours and the amount of sunshine.

After preparing the initial data, by means of the Input analyzer Software, the distribution function of each part is estimated.

At first by means of weather temperature and the amount of sun radiation, the amount of input energy can be estimated.

There are some notable points about the model as follows;

1. The input and output are expressed in terms of energy packages that is considered to be entered into the system in very small time interval.
2. The number of collectors directly affect energy absorbing. And the amount of energy which is counted as energy packages, after entering to this module by multiplying the absorption area (all the collectors) , can be entered to next stage. Obviously, the amount of energy absorbed, increases by adding new collectors.
3. The distribution function of all entery data, that are required to be entered in to the system, must be estimated first, and then they can be used in the problem.
4. It can be seen that in some steps in the system, Energy is sent to several different stages,Therefore it is necessary to use the Decide Module,in order to clear what percentage of the energy per unit or with what conditions, is imported to other parts.
5. The number of sunny hours determines the simulation lenght

Finally the thing that should be received from the system is the amount which is stored in Record Module.

Here there is cost constraint for a single purpose(cooling system) :

$$CSC + EPC > MC + ((CC + AC))/6 \qquad (3)$$

The budjet constraint of system implemetation:

$$\text{Budjet} = CC + AC + MC \qquad (4)$$

Table 3. Formulas Abbreviations

Full words	**Abbreviation**
Annual cooling supply cost	CSC
Anuual environmental polutions of using conventional systems cost	EPC
Annual maintenance cost	MC
Collectors cost	CC
Accesories cost	AC

In figure 3 part of the designed model by Arena Simulation Software is shown.

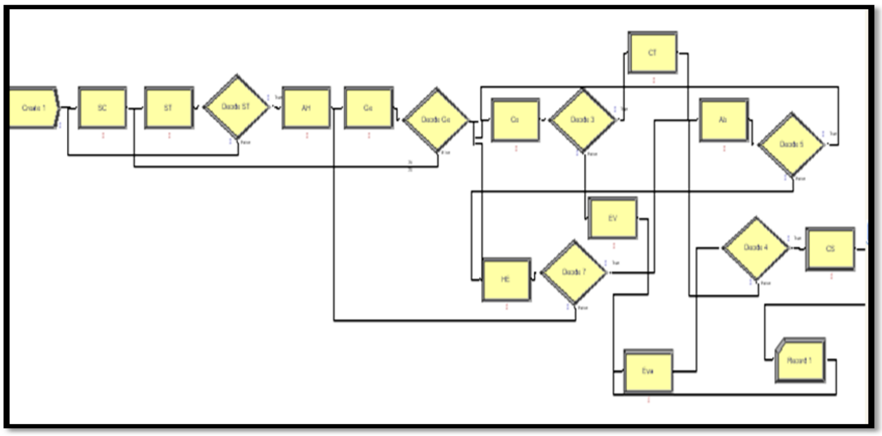

Figure 3. Part of the designed model by Arena Simulation Software

4. Conclusion

According to the discussed issues, the necessity of applying renewable energies, and solar energy for domestic uses in the form of solar absorption chiller, became almost clear. Advantages like energy saving, preventing from the environmental pollution and yet being economical [9]. Also Solar systems require less maintenance and are more ideal for distant and impassable places [9].

Implementing solar panels and powerhouses in far and urban areas, prevents from spreading the pollutions and the cost of constructing transmission and distribution network, will be removed [9]. However, the tendency of consumers to take advantage of this product won't increase until the time that government considers electricity and gas subsidies and collector prices are not acceptable.

Through this study it that by means of simulation - optimization modeling an approach for economic evaluation of solar heating and cooling systems was presented, in order to help analysts and system administrators, to be able to overcome the nonlinear relations to make the best and most economical decision with greater accuracy and performance at a lower cost.

Reference:

[1] H. Vidal, R. Escobar, S. Colle, "Simulation and Optimization of a Solar Driven Air Conditioning System for a House in Chile", Proceeding of the ISES Solar World Congress: Renewable Energy Shaping Our Future, **(2009)**.

[2] A. Abedi, "Utilization of solar air collectors for heating of Isfahan buildings in IRAN", 2nd International Conference on Advances in Energy Engineering (ICAEE2011) **(2011)**.

[3] R. Kharchi, B. Benyoucef, Y. Bartosievicz,, Jm. Seynhave, A. Hemidi, "The effect of solar heating gain on energetic thermal consumption of housing", Procedia of Engineering, Vol. 33, pp. 485 – 49 **(2012)**.

[4] K.F. Fong, T.T. Chow, Z. Lin, L.S. Chan, "Construction Guidelines for Solar Cooling Feasibility Studies and Analysis of the Feasibility Studies", Applied Thermal Engineering, Vol. 30, pp. 220–228 **(2010)**.

[5] Climasol., "Construction guidelines for solar cooling feasibility studies and analysis of the feasibility studies", ALTENER Project No. 4.1030/Z/02-121/20 **(2005)**.

[6] A. Falahatkar, H.R. Akhavan Armaki, "Solar absorption chiller system design in Tehran and the investigating performance of this system compared with conventional Chillers", Iran Energy Journal, Vol. 14, No.1, **(2011)**.

[7] M. Dehghani, M. Arabi, "Technical and Economic Evaluation of Solar Absorption Chiller Systems in Iran", Iranian Chemical Engineering Journal, Vol. 9, No.46 **(2010)**.

[8] H.R. Feili, P. Naderipour, F. Moghadasi, "Approach of Using Solar Energy in order to Move towards the Construction of Green Buildings", Iran Building Energy Conference **(2011)**.

[9] R. Peyman, "Introducing the performance of absorption chiller and smart solar panels in the building industry", 11th Conference of Civil students across the country **(2004)**.