



## Modelling and Simulation of a Double Effect Absorption System LiBr-H<sub>2</sub>O of Low Capacity Activated with Solar Energy

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**Abstract**— *In this work, the Modelling and Simulation of a Double Effect Absorption System LiBr-H<sub>2</sub>O with a capacity of 16 kW (4.6 refrigeration tons) which is activated by solar energy and biogas is presented. Simulator was created using EES® platform (Engineering Equation Solver) and simulator validation was performed using experimental data and results from other simulators published in specialized journals. Through a parametric study the best operating conditions and design was found, showing that this type of sustainable cooling technologies can be operated by means of renewable energy and have great potential to be used in residential, commercial and industrial sector.*

**Keywords**— *Renewable Energy, Mathematical Model, Simulator, Absorption, LiBr-H<sub>2</sub>O*

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### I. INTRODUCTION

With rapid energy demand growth worldwide, human beings have to face more energy scarcity and environmental issues. The conventional technologies to produce useful energy product, such as electricity, normally results in considerable environmental pollution and non-renewable energy resource depletion. These interrelated challenges could be solved through the use of energy conversion enhancement, waste heat recovery and renewable energy resource utilization [1].

The invention of the absorption refrigeration cycle goes back to the 1700's, for the years 1859 and 1950 were first used mixtures of ammonia/water and water/lithium bromide respectively work. Recently, the increase in the cost of electricity and environmental concerns have made the heat from renewable energy sources for absorption refrigeration systems are attractive for application in residential, commercial and industrial sector option.

The vapor compression systems have been used in many applications of refrigeration and air conditioning equipment. However the increase of global warming and the environmental impact of chlorofluorocarbons has stimulated interest in the development of absorption systems. The research and development of new efficient technologies as the foundation have the means to be environmentally friendly. Systems absorption cooling are attractive because they can be employed natural refrigerants (water, ammonia, etc...) Which satisfy the regulations of the Kyoto protocols and Montreal, coupled with this can be powered by solar energy, biogas, waste heat or geothermal energy, thus avoiding the use of fossil fuels. Therefore, absorption systems powered by renewable energy are seen as one of the most convenient ways to reduce emissions of greenhouse gases such as CO<sub>2</sub> [2].

The energy sources available for the operation of absorption systems can be classified into two groups: non-renewable and renewable. Non-renewable is that which is contained in fossil fuel: such as coal, oil and natural gas. In more specific terms the proposed system may use electricity, fuel oil, diesel, LP gas, natural gas, petroleum some are and others are obtained from the same and are commercially available. Renewable energy sources have a long life in terms of human existence, and therefore they are considered eternal. Examples include biomass, solar, wind, hydro and geothermal, without neglecting renewable hydrogen because the absorbing system can be coupled to a fuel cell [3].

Cooling systems today use two pairs of Refrigerant / Absorbent; Water / lithium bromide and ammonia / water. While the absorption system water / lithium bromide is commonly used for air conditioning system with ammonia / water can be used for applications where temperatures need to be below zero degrees Celsius, however has the disadvantage the high miscibility of ammonia and water which means that large rectification columns are required to generate ammonia, which adds to the complexity of the system [4].

The potential of the absorption systems is found in a decrease of electrical energy consumption inside and outside of the peak hours, to use waste heat, to increase the efficiency of the cogeneration systems by producing simultaneously electricity, heating and cooling, environmental protection and economic benefits for the user [5].

Therefore the need to study in detail the air conditioning systems space by absorption and exploit the virtues that count, unlike mechanical compression systems, so we proceeded to the creation of a specific character simulator basically is a management model aimed at model designed specifically for this case the system LiBr-H<sub>2</sub>O absorption low capacity in order to investigate their behaviour under different operating conditions.



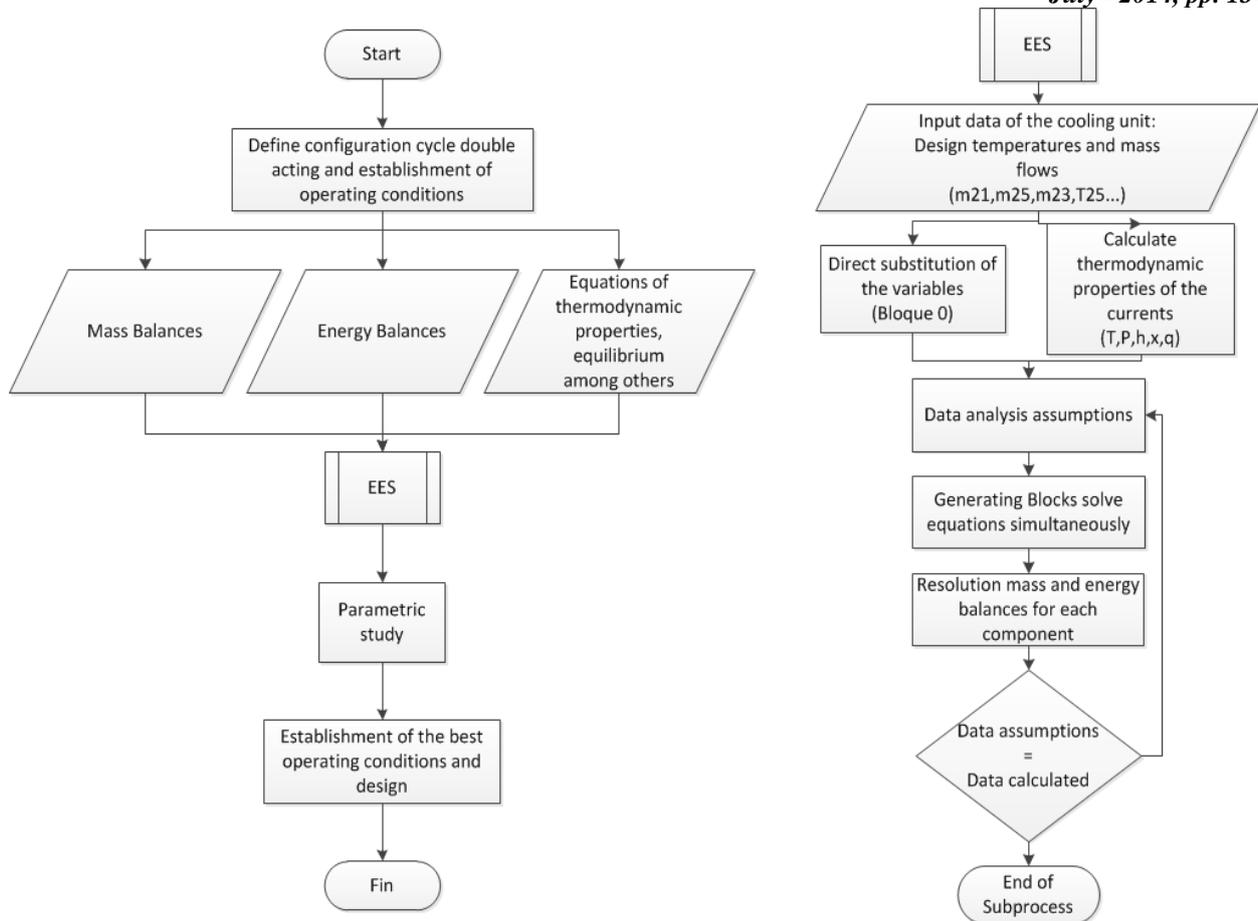


Fig. 2 Algorithm of solution absorption cooling system.

### Thermodynamic analysis

For the thermodynamic analysis of the absorption system the principles of conservation of mass and energy are applied to each system component.

### Conservation of Mass

This provides for the total mass balance of each material and the solution. The equations governing the conservation of mass for a system of steady flow and steady state are:

$$\sum m_{in} - \sum m_{out} = 0 \quad (1)$$

$$\sum m_{in} \cdot x_{in} - \sum m_{out} \cdot x_{out} = 0 \quad (2)$$

Where  $m$  is the mass flow rate and  $x$  is the mass fraction of LiBr in the solution. The mass fraction of the mixture at different points of the system is calculated using the respective temperature and pressure data.

The mass flow rate of refrigerant is obtained by the energy balance in the evaporator and is given as:

$$m_9 = Q_{eva} / (h_{10} - h_9) \quad (3)$$

### Conservation of energy

By the first law of thermodynamics, energy balances of each component (each component can be treated as a control volume with inlet and outlet streams, heat transfer and work interactions) of the absorption system are obtained as shown then:

$$(\sum m_{in} \cdot h_{in} - \sum m_{out} \cdot h_{out}) + \sum Q_{in} - \sum Q_{out} + W = 0 \quad (4)$$

The equations of energy balance for some components of the double effect are expressed as follows:

Evaporator

$$Q_{evap} = m_{10} \cdot h_{10} - m_9 \cdot h_9 \quad (5)$$

Absorber

$$Q_{abs} = m_6 \cdot h_6 + m_{10} \cdot h_{10} - m_1 \cdot h_1 \quad (6)$$

Condenser

$$Q_{cond} = m_7 \cdot h_7 + m_{19} \cdot h_{19} - m_8 \cdot h_8 \tag{7}$$

Generator (HTG)

$$Q_{HTG} = m_{14} \cdot h_{14} + m_{17} \cdot h_{17} - m_{13} \cdot h_{13} \tag{8}$$

In this article, the COP adopted for performance evaluation cycle. It is defined as the ability to output divided by the heat input given by:

$$COP = Q_{evap} / Q_{HTG} \tag{9}$$

By combining the equations of the system, the COP can be expressed as:

$$COP = ((m_{10} \cdot h_{10} - m_9 \cdot h_9 - m_{27} \cdot h_{27} + m_{28} \cdot h_{28})) / ((m_{14} \cdot h_{14} + m_{17} \cdot h_{17} - m_{13} \cdot h_{13} - m_{21} \cdot h_{21} + m_{22} \cdot h_{22})) \tag{10}$$

#### IV. RESULTS AND DISCUSSIONS

Machines double effect absorption has been developed with the aim of increasing the efficiency of the cycle relative to that provided by the single effect. They differ from these, from the structural point of view, mainly by the presence of two refrigerant vapor generators instead of one. This configuration allows increased production of cooling which results in an improvement in machine efficiency. To achieve this purpose, the heat supplied to the cycle requires a higher temperature level than in single direction. Thanks to this higher temperature level, the refrigerant vapor produced in the first generator (referred to as high temperature) will be able to cause boiling of refrigerant contained in the solution flowing through the second generator (so-called low temperature). Therefore, while in single action is sufficient heat source at 70-90 ° C in the double effect thermal source can reach and even exceed 150 ° C [7].

##### Validation of the simulator

To validate the proposed simulator is taken as a reference to the article published by Hongxi [8], because this presents simulation results and experimental study of a unit of LiBr-H<sub>2</sub>O absorption. The simulator was fed with the reference handling considerations; the results were evaluated and subsequently carried out a comparative analysis. In Table 1 the numerical value of the heat energy transferred to each of the components, both reported by the prior reference, as obtained by the specific simulator is developed.

Another point was to evaluate the behavior of the simulator unit effect suffered by the COP when the cooling load is changed, the values of proposed simulator were analyzed together, a reference simulator and experimental study. The behavior of the unit is given properly, this is inferred when comparing trends between the data presented in Figure 3. On average variation between the proposed and reference simulator simulator does not exceed 7%. For the experimental results the difference is less than 10%. These differences are largely in the values of the thermodynamic properties of the system currents.

TABLE I  
COMPARISON BETWEEN AMOUNTS OF HEAT SIMULATORS TO TRANSFER EACH COMPONENT UNDER THE SAME CONDITIONS FOR DESIGN

Component	Simulator (kW)	Hongxi et al. (kW)
Absorber	22.1	21.3
Evaporator	16	16
HTG	12.6	13.8
LTG	9	9.7
Condenser	8.2	8.1
HEHT	2.5	2.1
HELT	3.8	3.9

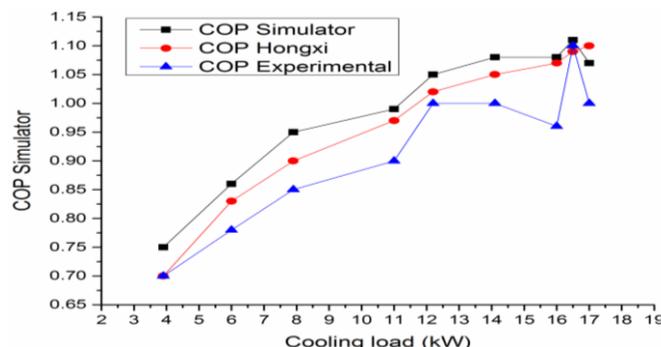


Fig. 3 Comparison of the coefficients of performance between simulators and experimental data.

Considerations simulator

The system simulation is carried out taking into account the following assumptions:

- The analysis is performed under stable conditions.
- The coolant (water) to the outlet of the condenser is saturated liquid.
- The coolant (water) to the evaporator outlet is in saturated vapor.
- The lithium bromide solution in the absorber outlet is a strong solution and is the temperature of the absorber.
- The temperatures absorber outlet and generators correspond to the equilibrium conditions of the mixing and separation, respectively.
- The pressure loss in the piping and heat exchangers all are negligible.
- It is considered that there are no heat losses to the atmosphere of the different system components (adiabatic components).
- System rejects heat to cooling water in the condenser and absorber.

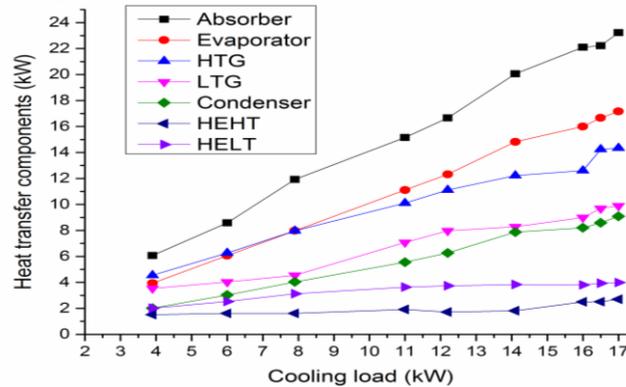


Fig. 4 Number of heat transfer component to different loading conditions.

## V. CONCLUSIONS

In this paper the mathematical modelling and simulation of a cooling system by absorption LiBr-H<sub>2</sub>O low capacity appeared to join the residential, commercial and industrial sector through the implementation of renewable energy, a validation was performed by comparing different conditions specific simulator operation between a simulator created and published in an international journal with finding a level of variation not more than 7%. According to the simulation performed best operation conditions for a load of 16 kW in the evaporator, activation requires a temperature in the high temperature generator approximately 150 °C which are easily reached by the heat generated from the burning of biogas (800-1000 °C) and the placement of solar thermal collectors as low and medium temperature are evacuated tube collectors (50-200 °C), compound parabolic collector (67-287 °C), Fresnel reflector (67 - 267 °C) and parabolic cylinder (67-267 °C).

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