23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

APPLICATION OF FUZZY LOGIC IN THE CONTROL OF CRYSTALLIZATION IN A COOLING SYSTEM BY ABSORPTION WITH WATER- LITHIUM BROMIDE PAR

João Erivando Soares Marques
Federal Institute of Education, Science and Technology of Bahia - Campus Vitória da Conquista-BA-IFBA
Avenida Amazonas, 3.150 - Zabelê - Vitoria da Conquista-BA, e-mail (joaoerivando@yahoo.com.br)
Carlos Antonio Cabral dos Santos
Federal University of Paraíba, Graduate Program in Mechanical Engineering -UFPB/PPGEM. Technology Center, Campus I, University City. CEP: 58051-900, João Pessoa-PB, Brazil. e-mail (carloscabralsantos@yahoo.com.br)
Francisco Antônio Belo
Federal University of Paraíba, Graduate Program in Mechanical Engineering -UFPB/PPGEM. Technology Center, Campus I, University City. CEP: 58051-900, João Pessoa-PB, Brazil. e-mail (belo@les.ufpb.br)

Abstract. *This paper presents the theoretical and experimental study of a control system for a steam generator. This system was developed to control the crystallization of an absorption refrigeration system. The control system keeps the generator pressure above the zone of crystallization of temperature-pressure- concentration diagram of saturated solution of LiBr-water. The control is accomplished through the simultaneous use of the relay and the frequency converter. The frequency converter operates at the speed of the pump drive motor of the tower of the cooling of the condenser, while the relay operates at the burner of generator, consecutively in the thermal combustion. The control system can operate in any reference values of pressure above the zone of crystallization of the absorption refrigeration system. In flow control were used techniques control and Fuzzy Modeling to control the thermal combustion power, on-off control. Ten different experiments were undertaken, which prove the efficiency of the system of control*.

Keywords: *Refrigeration by Absorption, Control Fuzzy, Crystallization, Natural gas, Frequency converter.*

1. INTRODUCTION

The demand for power generation alternatives has been the tonic in the current national and international scene, when discussing the need to have reliable power, clean, fast installation and safe (Cantarutti, 2011). With the reduction of energy sources and the increasing level of air pollution, the research centers are seeking to maximize the available energy use, making use of cogeneration systems (Pereira, 2006).

In this way, the more efficient use of energy is a subject of extensive research in universities and of great interest in companies due to using more aware of available natural resources and financial gain proportionate. Among these studies, there are the researches on cooling systems where energy economy is directly linked to the operating efficiency of your components (Geniêr et al., 2013).

In this scenario, the reduction of energy consumption spent by refrigeration and air conditioning installations is of great importance. Within this possibility, cooling systems for absorption can become an interesting alternative, because in some industrial processes are sources of thermal energy underutilized, as warm currents discharged to the environment or the burning of by-products of the production process. In establishments where not have the availability of thermal sources, can be used solar collectors as auxiliary power sources (Menna, 2008).

Absorption refrigeration systems have as their main source of heat energy, at relatively low temperatures. This heat can be supplied by burning a fuel, such as natural gas, or by waste heat from the process, as gas turbines and plants using water vapor, making these systems an alternative for cogeneration systems (Cantarutti, 2011).

An absorption refrigeration system is a heat activated thermal cycle; it exchanges the thermal energy with its surroundings. The absorption systems are also called thermo-activated, because they require a heat source for their operation, thus can take advantage of waste heat from industrial processes, the burning of fossil fuels or solar energy. These characteristics, in particular, make them usable for cogeneration systems, which is the generation of electricity and increased use of thermal generation with cooling (Carvalho et al., 2010).

In the case of absorption refrigeration system using refrigerant as a pair of lithium bromide and water, which is to indirectly cool a room through the absorption process. This should be automated to avoid the crystallization of the solution, which can occur at low temperatures, which would cause the strangulation of the system and the operational failure. Crystallization occurs when blocking the pipe system, the attitude to be taken is in some way, heat the part where this fallout occurred, allowing the pump to circulate the solution, since the product formed is highly viscous. When this phenomenon occurs in the absorber, implies a lower condensing pressures.

When there is a lowering of the cooling water temperature (which feeds the absorber and the condenser) may occur liquid transport from the generator to the condenser, with the occurrence of crystallization of the absorbent solution in the low temperature heat exchanger (Júnior et al., 2004).

It was developed a control system for a heat generator cooling system by simple absorption effect extends the use of techniques and modeling Fussy and on-off control to resolve a problem of crystallization of lithium bromide

2. MATERIALS AND METHODS

2.1 Modeling the control system

The control system was designed for the control of crystallization of the refrigeration system by simple absorption effect, developed in the laboratory of Solar Energy (LES) UFPB, with a cooling capacity that can vary from 4 to 14 TR. his control to keep the pressure constant generator, above the zone of crystallization the diagram temperature-pressure-concentration of saturated solutions of LiBr-water. The computation process handles the actions for the rotational speed of the motor-pump of the condenser cooling tower and the pressure of the steam generator. The control system is formed by two controls (“Fig. 1”). The first controls the temperature of the generator, by varying the rate of heat transfer to the generator, what is obtained, controlling the pressure of generator through a reread of solid state installed in command of the burner frame generator, through on-off control. The second is formed by a Fuzzy controller, responsible for determining the frequency of driveline of motor-pump set. The Fuzzy controller was implemented in the Toolkit Fuzzy Logic Controller Design of Labview program. The frequency converter is responsible for maintaining the high pressure system in an optimal value.

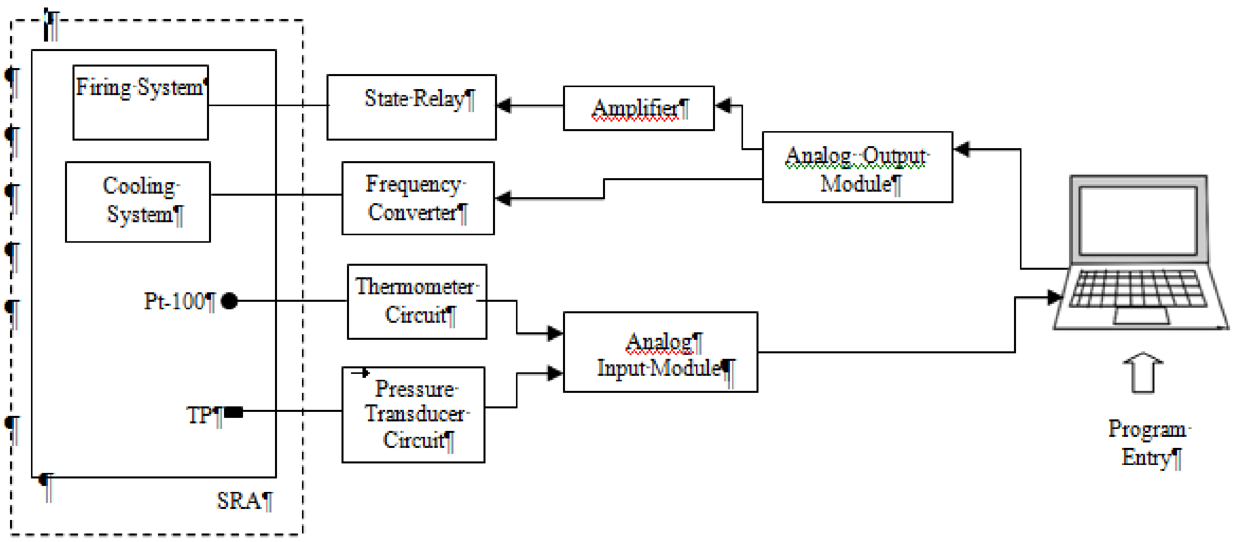

Figure 1. Schematic diagram of the control of the SRA (Absorption Refrigeration System)

2.2 Modeling of fuzzy controller

The fuzzy controller acts about the pressure of Absorption Refrigeration System, by varying the engine speed, made possible by the use of converter. With this, the rotation of the pump-motor set to tailoring required flow rate, in function of constant pressure in the operation line. In this way by varying the flow of water from the condensation Tower.

Linguistic variables controller were chosen so as to enable control of pressure of the generator. variables linguistic of the input of the controller: the pressure generator, variable defined on the basis of measurements of the pressure transducer and represents the value of pressure that will set the temperature of the generator; condensation temperature, variable defined on the basis of measurements of the temperature sensor PT-100 and the output variable, frequency variation of supply voltage of the pump motor set.

The linguistic variables of input and output of the fuzzy system, the quantity and format of the functions of relevance and the universe of discourse were chosen based on the nature of the process to be controlled and experimental tests of absorption refrigeration system. The input variable TC (condensation temperature) was associated with seven membership functions: TBG (large low temperature), TBM (average low temperature), TBP (small low temperature), TM (average temperature), TAP (high small temperature), TAM (large high temperature).

The membership functions were determined through recommendations of literature and heuristic knowledge extensively tuned through simulations and experimental tests. The set of membership functions follows a formed typical the presented in literature, where the terms are frontier trapezoidal and the rest of the terms is triangular.

In “Figure 2” are the membership functions related to the linguistic variable Temperature of condensation.

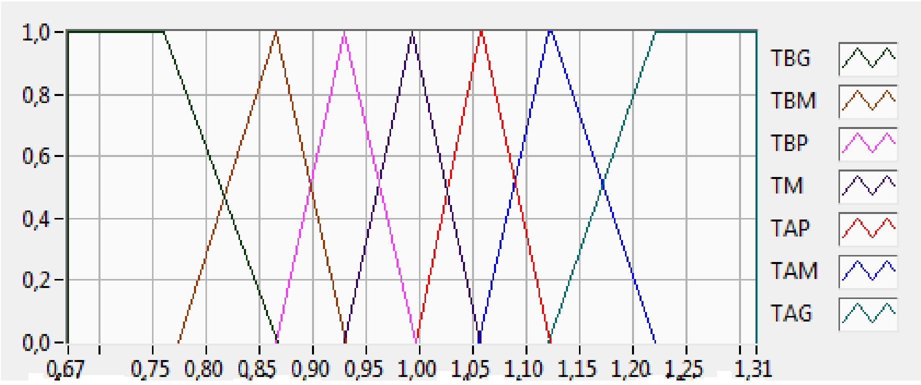

Figure 2. Membership functions of linguistic variable condensing temperature

The input variable PG (generator pressure) was associated with seven membership functions: PBG (large low pressure), PBM (average low pressure), PBP (small low pressure) PA (average pressure), PAP (small high pressure), PAM (average high pressure), PAG (large high pressure). Along with the other membership functions of the linguistic variable of the pump rotation, these seven membership functions were also implemented to serve as subsidies in the choice of output variable

The membership functions of generator pressure also were determined through recommendations of literature and heuristic knowledge extensively tuned through simulations and experimental tests. Found that the decrease of the outflow of cooling tower condenser implied an increase in pressure in the generator. The set of membership functions follows a typical formed presented in literature, where the frontier terms are trapezoidal and the rest of the terms is triangular. The “Figure 3” shows the membership functions related to the linguistic variable the of generator pressure.

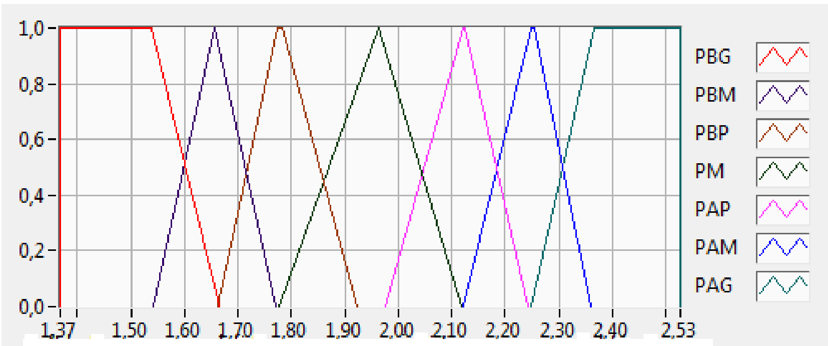

Figure 3. Membership functions of linguistic variable of pressure generator.

The output of the control system is the frequency variation of supply voltage and is directly related to the pressure measurements of the generator and the temperature of the condenser. The output variable VC (flow of cooling tower condenser), was associated with seven membership functions: VBG (large low flow), VBM (average low flow), VBP (small low flow), VM (average flow), VAP (small high flow), VAM (average high flow), VAG (large high flow). This membership function is determined from the input functions and represents the various values that can be implemented to the rotation of the pump, as the need of the system. VBG is related to increased pressure generator, because when implemented will decrease the pump rotation, VAG is related to the reduction of condenser pressure, when implemented will rise the rotation of the pump. In “Figure 4” shows the membership functions related to the linguistic variable of flow.

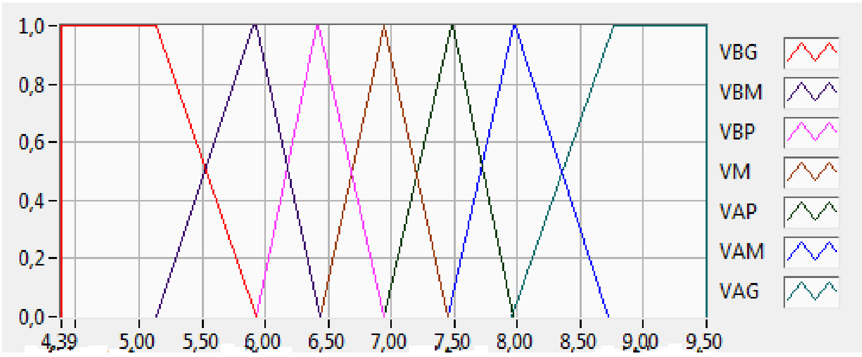

Figure 4. Membership functions of linguistic variable of flow

2.3 Control on-off

The on-off control acts on the thermal input of combustion through the solid state relay that inhibits or disables the burner, controlling the pressure of the steam pressure generator. The temperature of the generator varies according to the required pressure PG. The on-off control was developed in Labview program, in which implemented a vi of the source code to decide the action on the PG control variable, So if the pressure of generator is less than or equal to the desired pressure then burner enabled, otherwise disabled.

3. RESULTS AND DISCUSSIONS

Were fixed pressure values of the generator with respective frequencies of the pump of solution with water and lithium bromide. The control system has actuated in the thermal combustion and in the flow of the cooling tower condenser. All pressure values of the generator had errors between 0.01 the 9.97%. These errors are due to the thermal inertia of the system, because the burner has a delay of 40 seconds after operation. The variable of the control of the pressure of the generator has reached the reference value and remained within the range, ie, outside the zone of crystallization according to the diagram temperature-pressure-concentration of saturated solution of H_2O-LiBr.

The “Figure 5” shows the behavior of the curves of pressure of the steam generator with respective values during the experiments, in which the control system actuated to maintain the values of pressures within the allowed range.

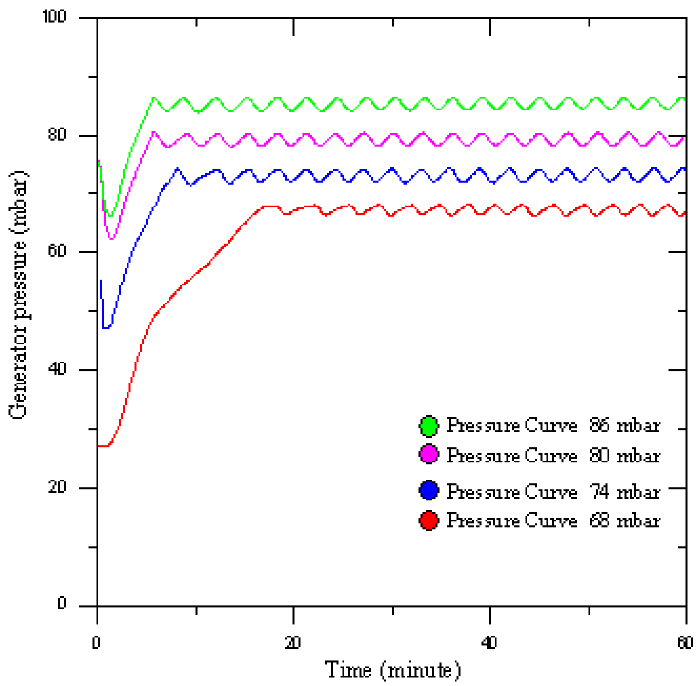

Figure 5. Pressure of the steam generator

In “Figure 6”, with control on the pressure of generator and the level of solution, it was possible to control the pressure of the absorber, remaining around 8.80 mbar. Thus controlling the cooling capacity on thermal load variation, reflecting the variation in demand for cooling in the evaporator. Avoiding the freezing of the refrigerant due to pressure drop in the evaporator. The flow of the cooling tower condenser was around 0.73 l /s (“Fig. 7”). In the experiment with the generator pressure value around 86 and the pump flow solution of water and lithium bromide in 0.0690 l/s. Were generated the graphics of the figures below. The pressure of the generator was close to the reference value, the temperature in the generator was 71°C (“Fig. 8”). The fuzzy control system acted on the flow in Tower of condenser through the two input variables, the pressure of the generator and the temperature of the condenser (“Fig. 9”). This system assists in the control of the generator of pressure, therefore to increase the temperature of condensation, decreases the flow of the tower of condenser, implying the increase in condensing temperature. There was an increase in temperature at the inlet and outlet of the heat exchanger, because the solution has a pre-heated before reaching the generator, staying at the same temperature range. As well as the condenser temperature remained constant. The concentration of the solution of water and lithium bromide in the generator, there was a decrease, reaching 6%, however the concentration of the solution in the absorber ranged from 2.5%, but remained constant.

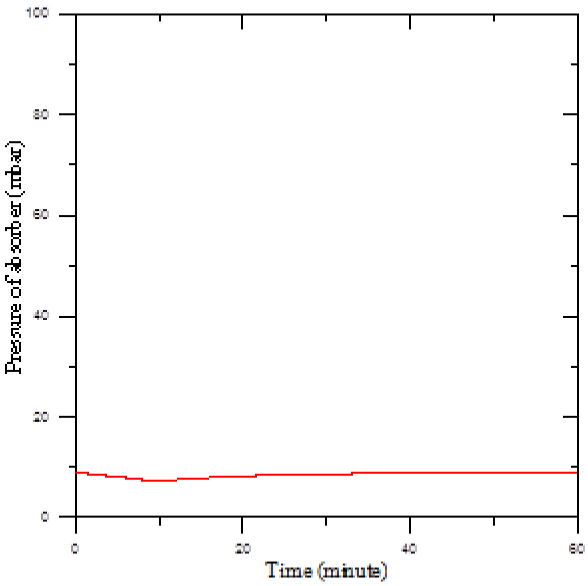

Figura 6 – Pressure of absorber

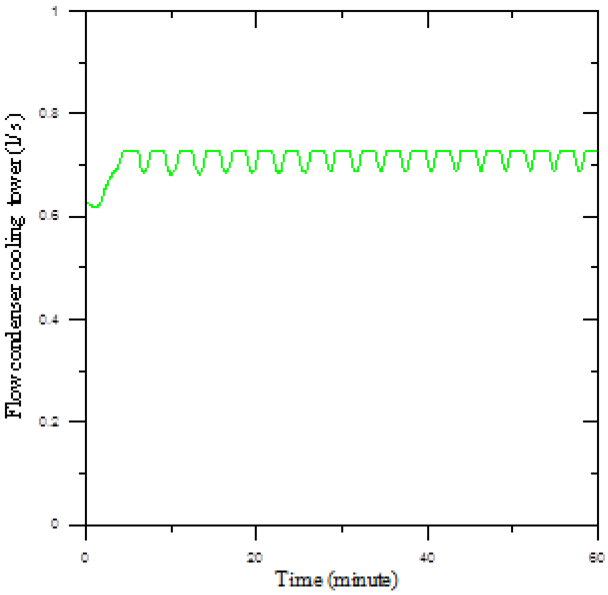

Figura 7 – Flow Condenser cooling tower

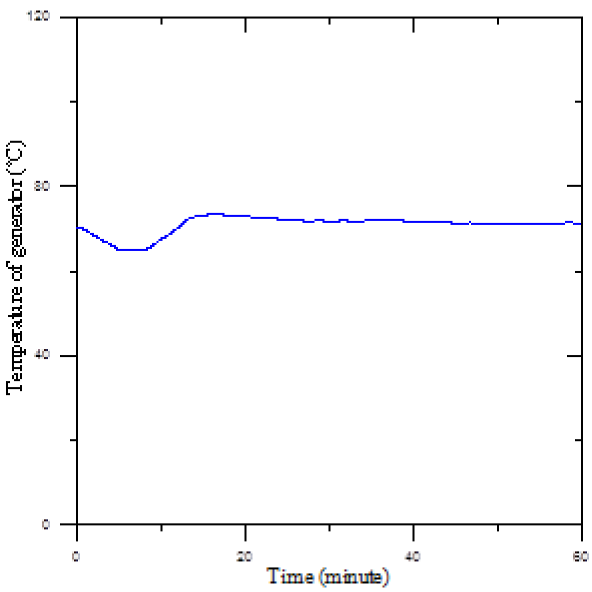

Figura 8 – Tempeature of generator

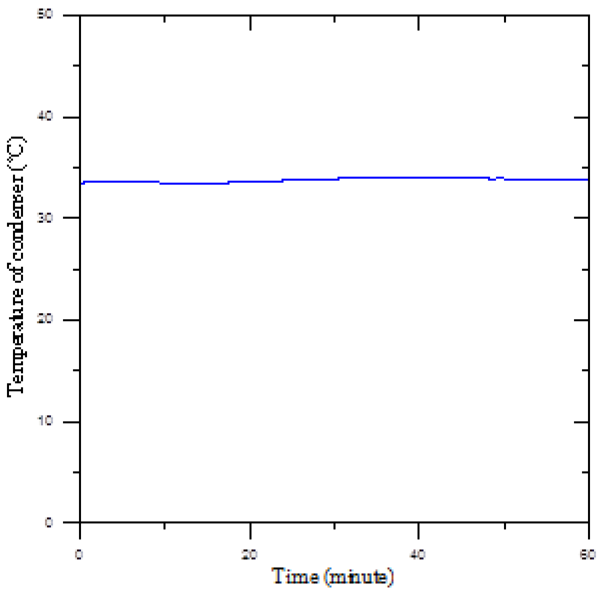

Figura 9 – Temperature of condenser

4. CONCLUSIONS

The following conclusions can be drawn according to the present study:

Output variables controllers remained consistent when compared the experiments between themselves, having a perfect sync between the controllers.

The fuzzy controller showed to be satisfactory in controlling the flow of the cooling tower condenser, assisting in the control of the pressure generator through the measurements of variables, system pressure and the temperature of the condenser. Controlling the temperature of the water of condensation and consequently the cooling capacity of the system.

Fuzzy logic also showed greater ability to address the problems of non-linearity of the process dealing with uncertainty in a natural way, similar actions and human reasoning, without, therefore, create hard obstacles between a situation and another.

In this sense fuzzy logic, by the action of the frequency converter, proved to be a powerful tool for controlling the speed of rotation of set motor-pump, presented concise answers and robust, Since the conventional control techniques do not always respond well to a high degree of system nonlinearity.

The on-off control also showed satisfactory control of the thermal burning of combustion, may act in any reference values of pressure above the zone of crystallization of the absorption refrigeration system.

In this way, successfully concluded the applicability of the control system as a tool of the operation of absorption refrigeration system to control the crystallization.

5. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support of the CNPq/FINEP/RECOGÁS.

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7. RESPONSIBILITY NOTICE