ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

PID FLOW CONTROL FOR ABSORPTION REFRIGERATION SYSTEMS WITH PAIR WATER – LITHIUM BROMIDE

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Abstract. *This article describes the development of a flow control system for absorption chiller units with par water-lithium bromide, units that operate at negative pressure, where the measurement of flow by intrusive methods is not tolerated and the recirculation is promoted by low-power single-phase pumps. For that purpose was developed a testing bench reproducing the flow conditions concerning of saline water-lithium bromide, being the same properly instrumented with sensors and actuators. The interaction with the testing bench took place with the aid of a virtual instrument control, implemented in LabVIEW, which provided the communication and management of the same with the devices mentioned. Then was also implemented in LabVIEW, a system of closed loop control, with PID controller, whose first evaluation occurred by testing with water, allowing attest to the flow control, according to figures 7 to 10 and after appropriates precautions taken, the same was evident with saline water-lithium bromide.*

Keywords: *Refrigeration, Absorption, Control, Flow.*

1. INTRODUCTION

Absorption refrigeration units have been quite required, due to its potential to take advantage of waste heat to produce the cooling effect from cogeneration plants. This technology, due to the abundant availability of electricity, had been forgotten, replaced by compression refrigeration systems, which differ by making use of physico-chemical pairs refrigerant / absorbent using substances considered as non-offenders of the environment and also by the pressure elevation occurs in these systems for pumping and not by compression. By virtue of its potential, the refinement of the absorption refrigeration systems is verified as legitimate and his conditioning is possible through an appropriate control of recirculation flow, which is of significant importance to reach of optimal and remained operating conditions.

Recirculation in absorption systems with pair LiBr-H2O takes place by means of a hermetic pump with magnetic coupling, the use of these devices is due to the fact refrigeration units with LiBr-H2O operate at subatmospheric pressures (Herold , 1996). The actuation of these pumps is promoted from single-phase induction motors, due to be usually necessary fractional power pumps, whose change their revolutions can be satisfactorily achieved by a voltage controller, since it satisfies the prerequisites of simplicity , reliability and efficiency (Mademlis et Michaelides, 2004). Also according Mademlis et Michaelides (2004), the application of technologies that work by frequency variation in the stator, such as pulse width modulation PWM it would be impracticable in view of the complexity and costs involved.

A system would establish a comparison between an output and an input reference, using the difference as a means of control is called feedback control system (Ogata, 2003). The basic components of a control system correspond to the Sensor / Transmitter and Controller, through which information about the variable to be controlled are acquired and processed, so that control actions are generated and interventions are conducted (Bega et al, 2006) .

In this paper is developed a system of closed loop control, with PID action controller (Proportional-Integral-Derivative) for refrigeration units with the pair water-lithium bromide, being implemented in graphical language

LabVIEW (Laboratory Virtual Instrument Engineering Workbench), which from an experimental bench reproducing flow conditions concerning the saline water-lithium bromide, was attested to the control flow desired.

2. CONTROL SYSTEMS

A control system consists of subsystems and processes built with the purpose of obtaining a desired output with desired performance for a specific input supplied (Nise, 2002). Control systems maintain the controlled variable at the specified value, comparing the measured variable with the desired value (set point), performing the corrections as a function of deviation (error or offset) between these two values (Bega et al 2006). Information on the controlled variable are collected by sensors (Figure 1), through which they are converted into signals and sent to the control hardware, where through the controller, the comparison is done automatically with the set point and then is calculated, based on the offset, the values of the correction signals required to adjust the manipulated variable.

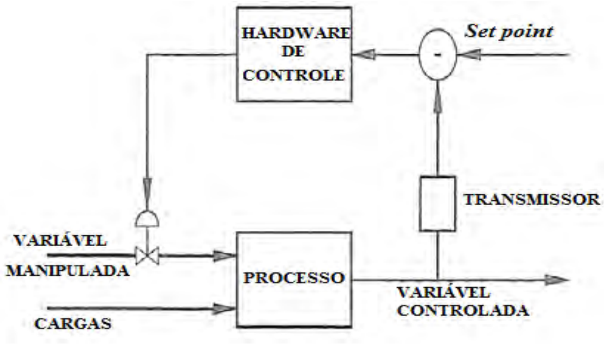

Figure 1. Feedback control systems (Bega et al, 2006)

The controller part of a mathematical model, which accurately represents the dynamic system that will be controlled, the model corresponds to differential equations which correlate input and output variables of the system.

According to Nise (2002), the control systems are unfolded in two main configurations: the Closed Loop Systems and the Open Loop Systems. The Closed Loop Systems, also denominated of Feedback Systems, they are distinguished of the Open Loop Systems for the fact of the output signals, in this control configuration, feedback the controller, minimizing the offset and reaching the set point (Ogata, 2003).

The way as the controller responds to the offset, generating the correction signal is denominated "control action" and it differs according to the peculiarities of the processes and the expected results. The choice of the best control action is product of a series of factors, among which stand out the operation easiness, costs and quality of the control.

The Proportional-integral-derivative (PID) control action consists in the respond to the offset by joint action of a controller proportional, integral and derivative, gathered in an only controller. According to Alves (2010), together with the elimination of the offset, characteristic of a Proportional-integral controller, this action adds the stability granted by the Proportional-derivative control, making possible a high proportional gain and with that a faster answer. The correlation that governs this control action, as well as the parameters of the controller's tuning, they are willing to proceed:

$$\mathrm{m(t)} = k_c . \mathrm{e(t)} + \frac{k_c}{\tau_i}\int_0^t e(t)dt + k_c \tau_d \frac{de(t)}{dt} + b \tag{1}$$

Where: m (t) - output signal from the controller;
e(t) - error (relative to the measured variable);
Kc - proportional gain;
τi - integral time, min;
τd - derivative time, min;
b - the controller output when the error is zero.

3. CONTROL STRATEGY

It was designed a workbench, figure 2, reproducing the flow conditions concerning of saline water-lithium bromide, the same consisted of a hydraulic circuit resulting in 6,87 m in stainless steel and PVC, and had as sensor of flow, a transit-time ultrasonic flowmeter (model UFM-170), once in absorption chiller systems with the pair water – lithium bromide, intrusive methods are not tolerated. These sensor make use of acoustic transducers, mounted in a spaced way (a the downstream and the other upstream of the flow), which send and receive pulses of high frequency, supplying the time for signal to travel between the two transducers, as decisive parameter of the flow.

The energy for flow is given up by a hermetic pump BOMAX (model NH-100 PX-T, 65 W, monophase) with identical technical characteristics the ones that serve the systems with the pair H2O-LiBr. The need to adopt a hermetic pump, besides guaranteeing the pressures of operation of these units, located below the atmospheric pressure, is due to the fact of the lithium bromide to be a hygroscopic salt, preventing, in this way, that influxes through gaskets or mechanical stamps, provoke the compromising of the thermodynamic properties of the solution water – lithium bromide.

Figure 2. Workbench

The pump had your rotation changed by a dimmer circuit, which acts according to the method of variation of the tension in the stator, as can be seen in figure 3, in him a potency key, the triac, is triggered in certain angle of phase of the sinusoidal signal, in such a way, that the applied tension to the load can vary from a maximum to a close value of zero (Fitzgerald et al,2006). The potentiometer used in the conventional dimmer, to adjusting the tension value in the trigger of the tiristor, it was substituted by a optocoupler MOC 3011, more specifically an optotriac, that corresponds a kind of tiristor, in which the triggering happens by light pulses, and these noted in a special area of the tiristor, through optic fiber. Your adoption, besides enlarging the range of tensions supplied to the pump, had as intention to allow the communication with a device of multifunctional acquisition of data (DAQ-Data Acquisition), responsible for the conversion .

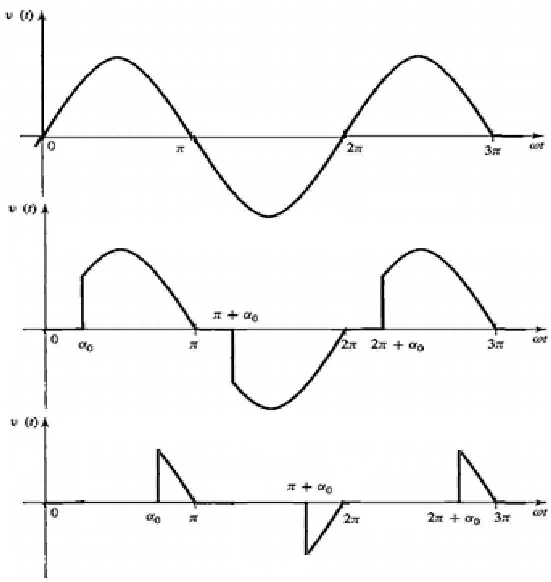

Figure 3. Voltage supplied to the load by trigger of the Triac

The management of both mentioned devices was under the responsibility of LabVIEW, which corresponds to a graphic programming language developed by National Instruments, of wide application in the monitoring and control of systems. The communication with ultrasonic flowmeter happens by port RS-232C through the Hyper Terminal software (WINDOWS), and with the dimmer via DAQ. The verification of the correct transmission of data and management was also under the responsibility of LabVIEW, it can be obtained by the construction of a virtual instrument VI and your respective front panel and block diagram. In the first case, comparing the informed data in the ultrasonic flowmeter screen with the informed ones by VI, and in the second, noticing that when requesting a tension change by VI, the dimmer respond, for your time, varying the feeding tension in the pump, caused to the flow change, which is soon noted by the ultrasonic flowmeter.

3.1 PID control

The figures 4 and 5 exhibit the referring schematic diagrams to PID control loop achieved. From that same it is observed that the feedback is provided by the ultrasonic flowmeter UFM-170 and that the minimization or elimination of the offset, task carried out by the controller, it was under the responsibility of the graphic language LabVIEW.

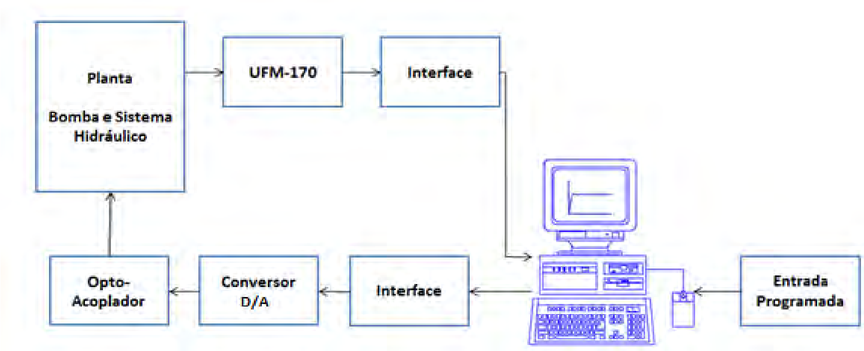

Figure 4. Instrumentation diagram concerning to the PID control flow system.

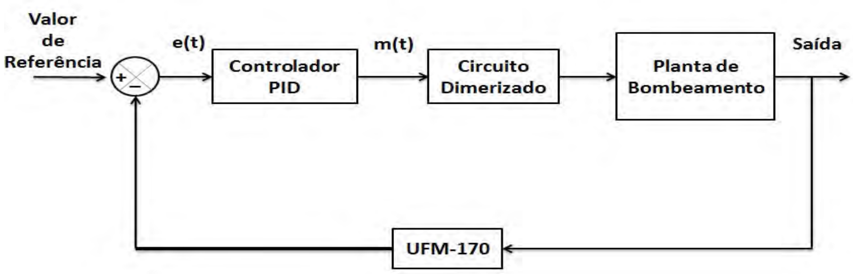

Figure 5. Block diagram of the PID flow control system.

4. EXPERIMENTAL RESULTS

Tests were accomplished initially with the water, in the intention of verifying with relationship to the effectiveness of the control, as well as to familiarize with your tuning through adjustment of controller PID parameters. These tests allowed the graphics flow (l / s) vs acquisition in time (1 acquisition / s), represented by the figures 6,7,8 and 9 through which can verify the intended control for water. One blank line must be included above and below each equation.

In the figures 6 and 7 it is noticed that just the parameter relative the proportional control was informed, in the case the proportional gain Kc, analyzing their influence on the system to be controlled. It is possible to observe a fast oncoming of the set point, however distant of an offset, a characteristic behavior of a proportional controller.

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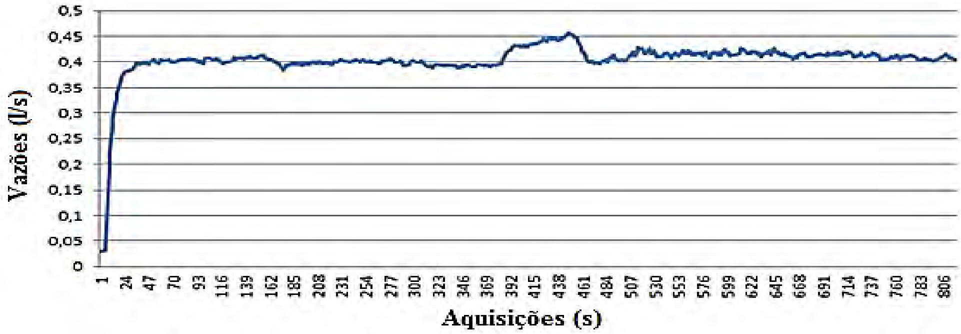

Figure 6. Proportional control for a flow of 0.5 l / s.

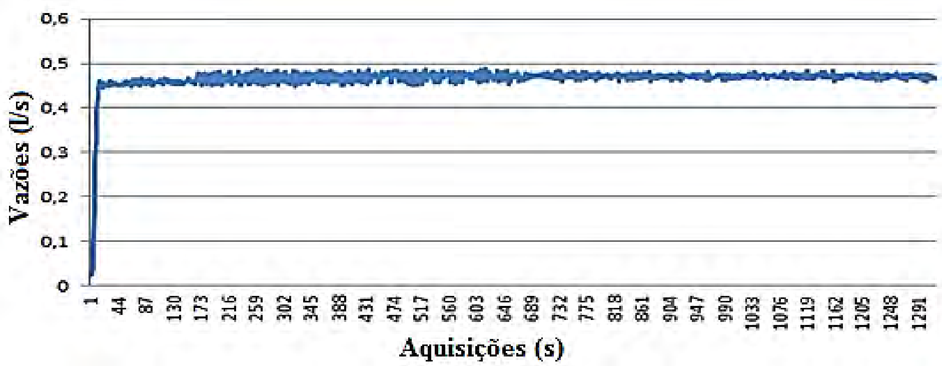

Figure 7. Proportional control for a flow of 0.5 l / s, with the tuning parameter Kc.

In the following test, figure 8, it was looked for to reach the elimination of the offset, informing referring values to the control PI (Kc and τi) and how can contemplated through the graph, there was the reach of the set point, as well as the increase of the stability, provoked by the addition of the integral action.

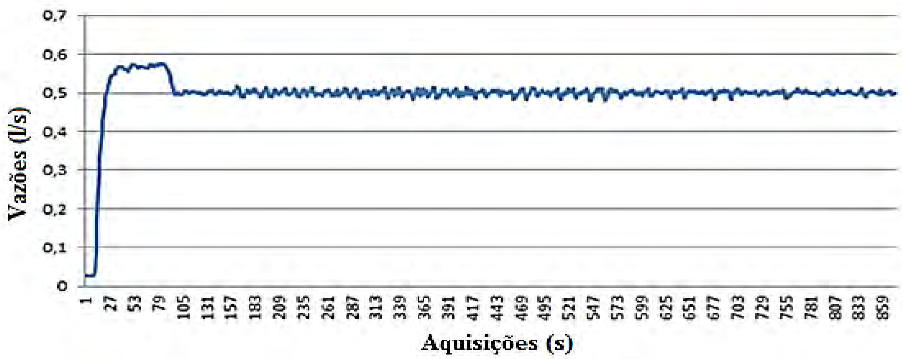

Figure 8. PI control for a flow rate of 0.5 l / s

The presence of three parameters to be tuned suggests a high number of possible combinations, hindering the process of the controller's tuning, incurring in the disadvantage of acting by interactive method. However the language graphic labVIEW offers means for obtaining of the automatic tuning, through the function Auto-Tuning, function that was added to the virtual instrument, allowing to reach the exposed graph in the figure 9.

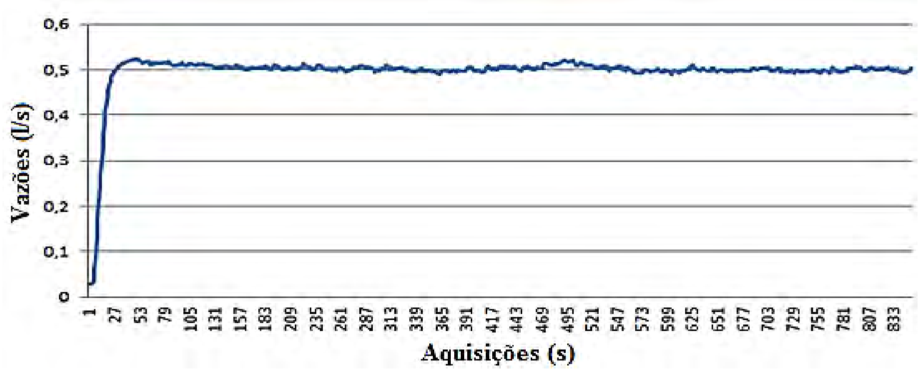

Figure 9. PID control for a flow rate of 0.5 l / s, with parameters Kc, τi and τd, achieved via automatic tuning process.

For the tests accomplished with the solution H2O-LiBr were necessary some precautions. The first of them consisted of the removal of the existent water in the hydraulic circuit, so that the properties of the saline solution were not compromised for remaining of water, in view of the characteristic hygroscopic of this solution. The second step resulted in, with the aid of the external routines present in Engineering Equation Solver - EES, ascertain whether the concentration of the solution was in around 52. 9%, condition required at section of recirculating in absorption chillers (Herold, 1996). Satisfied the mentioned conditions, the first test was performed with H2O-LiBr pair, which supplied the following result, figure 10.

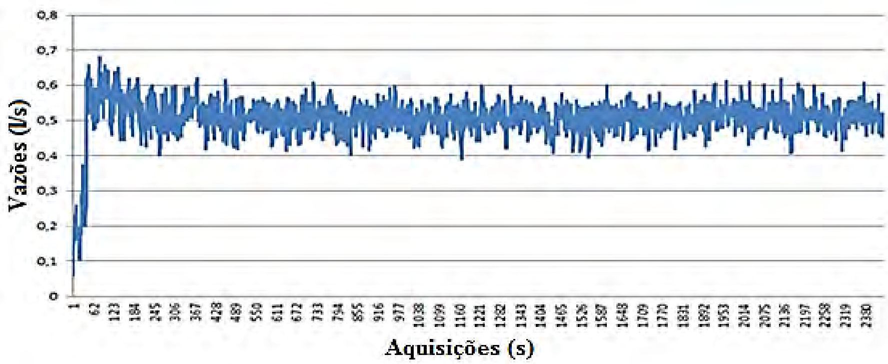

Figure 10. PID control for a flow rate of 0.5 l / s, the ratio 1 acquisition /30s

The flotations observed in the graph were already expected by the fact that does not have in ultrasonic flowmeter's database informations for LiBr-H2O solution, however the same possesses parameters that guarantee the reliability of the measurements, such as the force of reception signal S, signal quality Q and the coefficient of transit R, which it can be accompanied by the own ultrasonic flowmeter starting from your screen, being regulated the distance among the acoustic transducers. Such procedure was also accompanied by alterations in the time of acquisition, now in the ratio of 1 acquisition /30s. This measured it was shown interesting, by virtue of the absorption systems need of non-intrusive methods for flow measurement. Accomplished the mentioned adaptations, the graph that follow (figure 11) it corresponded to the application of the PID control established to the condition requested to a section of recirculation of an absorption chiller of double effect in series, which equals 0.046 l/s. The graph of the figure 10 corresponded to a adjustment via time series of the values disposed in the figure 11, with Intent to better demonstrate the performance of the proposed control, which reached a average relative error of 1.04% in relation to the set point.

ISSN 2176-5480

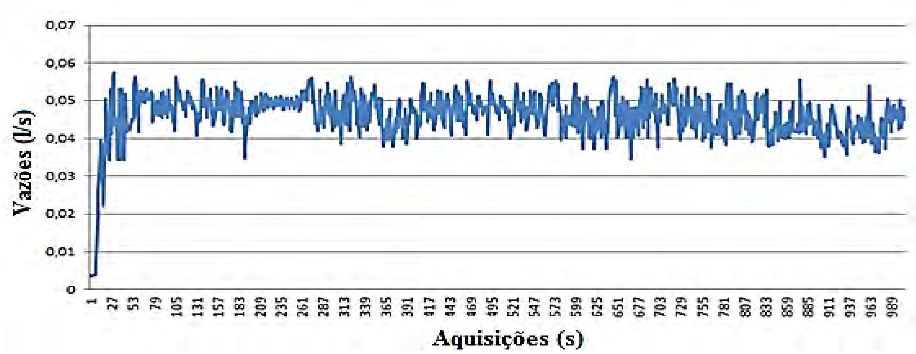

Figure 11. PID control established for a flow of 0.046 l / s

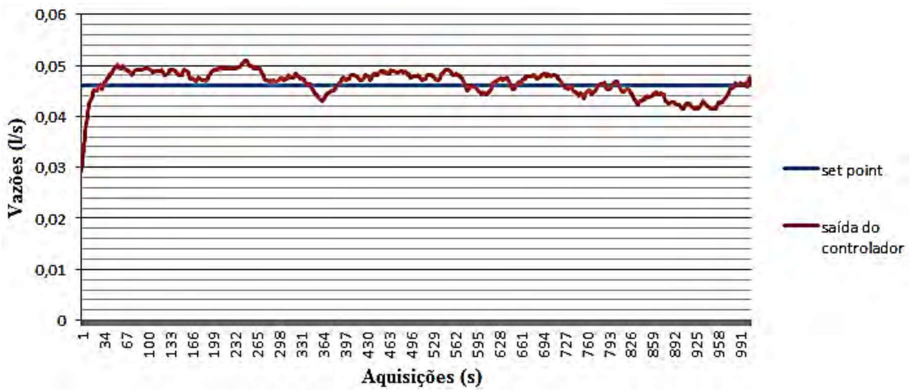

Figure 12. Results achieved via time series

5. CONCLUSIONS

The results obtained showed the success of the proposed control system, confirming its good performance and reach of flow control, initially for water, and then conducted after the adjustments within acceptable limits to absorption systems, the same was verified for H2O/LIBR saline solution. The good performance of the dimmer was also confirmed in its goal to vary the rotation of a hermetic pump, showing itself as an effective means to drive low power pumps.

The control system exposed by this Article shall provide the conditions necessary for the operation of theoretical experimental approaches, allowing to explore the potential of absorption chillers. The control shown may also act automation of the process of absorption systems, which will contribute corrective action in the crystallization processes of lithium bromide, since it is a solid salt in its pure form, are liable to crystallize itself.

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