2009 International Nuclear Atlantic Conference - INAC 2009
Rio de Janeiro,RJ, Brazil, September27 to October 2, 2009
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: 978-85-99141-03-8

DEVELOPMENT OF AN OBJECT-ORIENTED SOFTWARE BASED ON FUZZY-LOGIC FOR CONTROLLING TEMPERATURES IN PAC EXPERIMENTS

André L. Lapolli, Sueli Yamagishi, Claudio Domienikan; Roberto M. Schoueri; Artur W. Carbonari, Rajendra N. Saxena.

Instituto de Pesquisas Energéticas e Nucleares, IPEN - CNEN/SP
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
alapolli@ipen.br

ABSTRACT

The Hyperfine Interaction Laboratory at Instituto de Pesquisas Energéticas e Nucleares (IPEN) has been using Perturbed Angular Correlation (PAC) technique for studying material science for more than 20 years. One of the important aspects of the research involves the study of the behavior of measured properties of samples as a function of temperature. For temperatures higher than room temperature a small resistance furnace is used to heat the sample. The need to carry out the PAC measurement at predefined temperatures steps in a programmed manner is obvious. The present work describes a procedure for the furnace temperature control and automatic data acquisition at different temperatures based on fuzzy logic. The procedure consists in determining the linguistic input (*temp,* Δ*temp*) and output (*pow*) variables and their pertinence functions. After defining the variables, an object–oriented program is written in Java language which is an interface between principal data acquisition program and electronic temperature controller of the mini furnace. In addition to the implementation of the class that involves the fuzzy logic and classes with strategic algorithms defined for each temperature range there are classes of communication between systems based on modbus protocol RTU (Remote Terminal Unit) connected to serial interface RS-488. In this manner the applied technology for the development of software permits higher software life requiring only small alterations or implementation of classes in the use with new equipment.

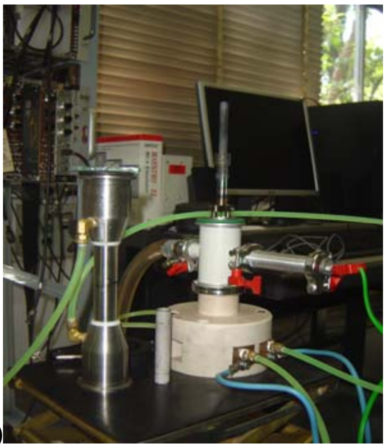
1. INTRODUCTION

In order to study hyperfine interactions in samples using Gamma-Gamma Perturbed Angular Correlation (PAC), it is often necessary to measure samples at different temperatures. The temperature variation and its control can be carried out either manually or automatically. The Hyperfine Interactions Laboratory of IPEN has acquired new equipment and peripherals to automatically acquire the experimental data at different temperatures. The present work describes a software system that has been developed based on fuzzy logic to control the temperature of the sample in a small tubular furnace with graphite resistance via communication interface in a microcomputer.

One of the automation methods consists of interfacing the electronic and programming systems, which simplifies the hardware and makes the system more flexible. The fuzzy logic permits a problem-solving control system methodology that can be implemented in systems ranging from simple small embedded micro-controllers to large, networked multi-channel PC or workstation-based data acquisition and control systems [1-3].

2. THE FURNACE

The furnace is a water cooled device with tubular graphite resistance element. Figure 1, show the photograph and a sketch of the furnace respectively.

(a) 

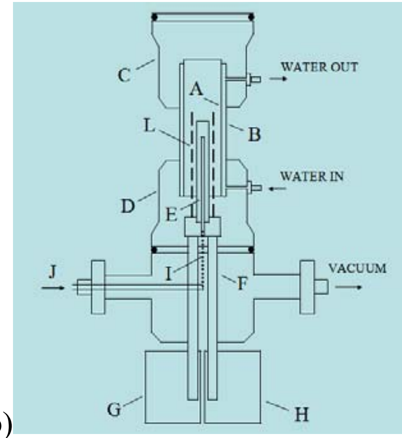
(b) 

Figure 1. Graphite resistance furnace: (a) general picture e (b) schematic drawing

The furnace consists of two concentric stainless steel tubes (A, B) with 0.5 mm wall thickness held together by an upper and a lower chamber C and D respectively through a set of neoprene O-rings. The upper and the lower ends of these chambers terminate in vacuum flanges. The space between the aluminum tubes serves for the water circulation. The provision for the water inlet and outlet are provided in the upper and lower chambers respectively. The assembly of tubes and chambers can be held under vacuum, as the inner tube is isolated from the water circulation system through O-rings. The lower chamber is coupled to a 4-way cross flange fitting, fixed at the center of the spectrometer table, having outlets for vacuum pump, a dual feed through for thermocouple connection and a dual electrode feed through for connecting the power supply to the graphite heating element. A semi split tubular graphite furnace is fixed on top of the electrodes and the thermocouple is fixed, through a support, inside the furnace. The radiation shield around the graphite heating element is a refectory alumina tube. The lower parts of the electrodes are also water-cooled. The sample to be heated is sealed in a quartz tube under argon atmosphere and placed inside the furnace from the top chamber. The top of the chamber is then covered with a flat glass plate placed on the O-ring and the system is evacuated to 10^{-5} mbar before heating the furnace. The power supply for the furnace has the capacity of furnishing 50 A at 60 VAC for the graphite heating element.

The micro-processed temperature controller, used for the furnace, was furnished by a local company Flyever (model FE50RP) and has up to 10 ramp/steps of temperature programming. A Platinum Rhodium 10% - Platinum (type S) thermocouple with ceramic protection tube is used for measuring the sample temperature. Commercially available software Flycon was installed in a personal microcomputer to control and read the sample temperature.

3. DEFINITION OF FUZZY SYSTEM

In order to measure the samples at temperatures above room temperature, a small tubular furnace with graphite resistance was designed and assembled (Figure 2). The Interface between the computer and the furnace temperature controller is the RS-485 (Modbus-RTU protocol) [4].

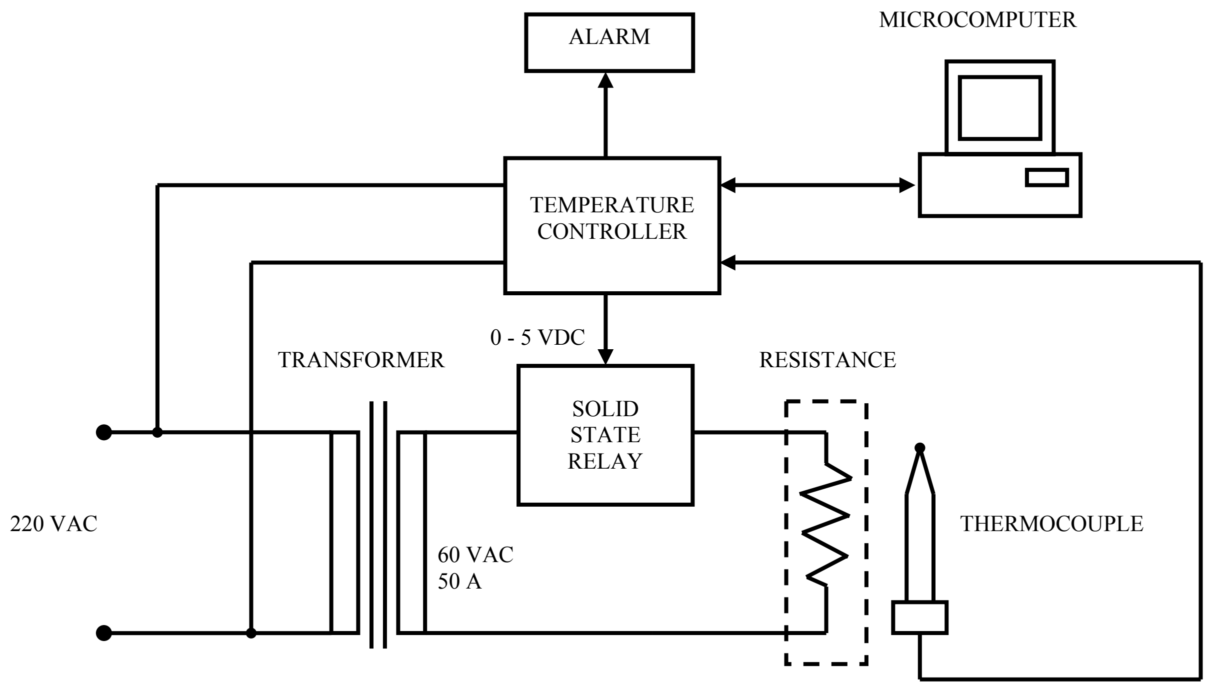


Figure 2. Block diagram of the small furnace for PAC spectrometer and power supply

The following procedures have been carried out to design the software:

- A software in Visual Basic language was developed to analyze the behavior of the furnace.
- The temperature as a function of time has been measured for each power level. (Figure 3).
- Determination of the input (λ-type function) pertinent variables (Figure 4, 5). The membership function μ (see figures 4-6) determines the degree of compatibility [3].
- The definition of the inference method that was made based on the Mamdani model [3] where the values of the output variables (power) were defined depending of each condition.

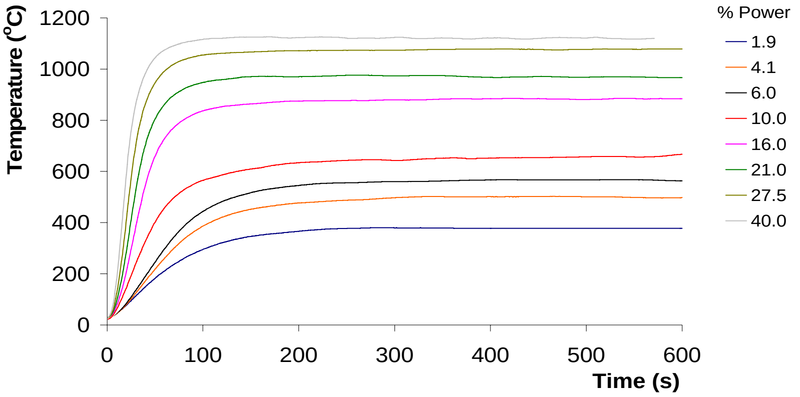


Figure 3. Temperature as a function of time for different power levels.

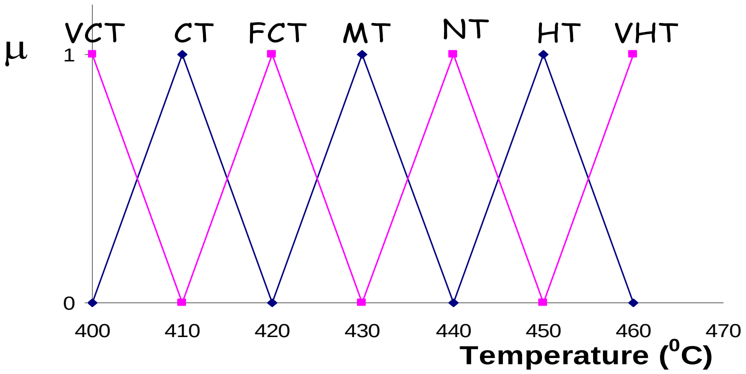


Figure 4. Input pertinence variable Temperature (*temp*): VCT -Very Cold Temperature, CT-Cold Temperature, LCT-Less Cold Temperature, MT-Medium Temperature, NT-Normal Temperature, HT-Hot Temperature, VHT-Very Hot Temperature.

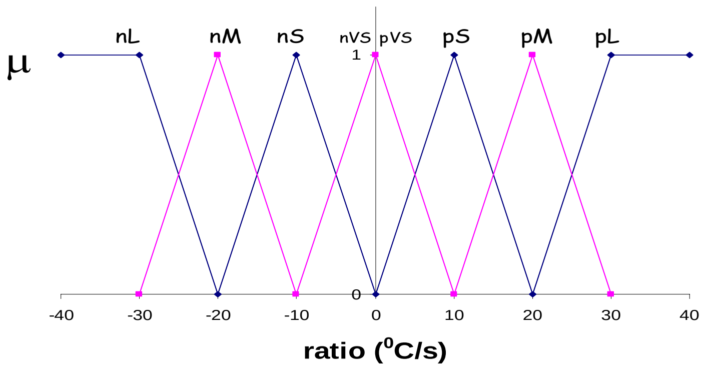


Figure 5. Input pertinence variable Temperature to time ratio (Δ*temp*): negative (n), nL-Large, nM-Medium, nS-Small, nVS-Very Small, positive (p), pVS-Very Small, pS-Small, pM-Medium, pL-Large.

- The Center-of-Maximum Method was chosen for the output variable of the defuzzyfication process. The results are shown in Figure 6 and Table 1.
- The combinations of the input and output variables resulting in the rules for fractional power are shown in Table 1.

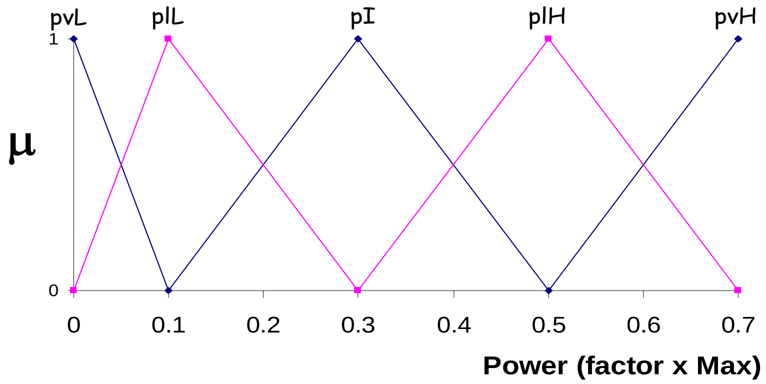


Figure 6. Output pertinence variable Factor to Maxima Power (*pow*): power (p), pvL-very Low, pIL-Low, pI-Ideal, pIH- High, pvH-very High.

Table 1. Rules for factor power output

Δtemp / Temp	VCT	CT	FCT	MT	NT	HT	VHT
nL	pvH	pvH	pvH	pIH	pIH	pIH	pIH
nM	pvH	pvH	pvH	pIH	pIH	pIH	pI
nS	pvH	pvH	pIH	pIH	pI	pI	pIL
nVS	pvH	pvH	pI	pI	pI	pIL	pvL
pVS	pvH	pIH	pI	pI	pI	pIL	pvL
pS	pIH	pIH	pI	pI	pIL	pIL	pvL
pM	pI	pI	pIL	pIL	pvL	pvL	pvL
pL	pI	pIL	pvL	pvL	pvL	pvL	pvL

With the definition of the variables, the selection rules have been created and applied in a MatLab software simulation.

As the interval of the variation of the furnace temperature is very large and since it works in two stages it was necessary to develop a strategy to define the temperature intervals and power in which, the numerical values of variables in fuzzification as well as in defuzzification vary. With this in mind a generic algorithm was created for acquisition, fuzzification, defuzzification which it was simulated in Visual Basic language applied to EXCEL tables.

4. SOFTWARE DESIGN

Hyperfine Interactions Laboratory usually works in two temperature regimes: 8 K- 300 K and 300 K- 1500 K. This results in two independent classes as shown in Figure 7. In Figure 8 the classes are highlighted in detail. The class CPM45 carries out all the data transmission process to the data acquisition system and the graphite furnace. Its particularities are related to the Modbus-RTU protocol, which it works in hexadecimal word and system of transmission validation CRC (Cycling Redundancy Check). In this manner a message received or sent should be validated so that the system can process and respond to a command sent through DATA ACQUISITION SYSTEM.

The class FUZZY receives the value of temperature obtained from the furnace thermocouple and the associated electronic system according to the structure shown in Figure 7. As described above the objective of this class is to obtain a value of the fraction of the power so that the furnace can attain the temperature with maximum efficiency and maintain it during the whole process of data acquisition. In this regard the process is managed by the super class manager who has the function of receiving the temperature value in real time, determine the ratio of temperature variation with time, inform the DATA AQUISITION SYSTEM about the defuzzyfication power and send the alert, should the temperature be different from the determined value so that the system stops the acquisition until the conditions determined in the process are restored. Based on this project the program has been developed and it is in the initial test phase. The results obtained so far are excellent.

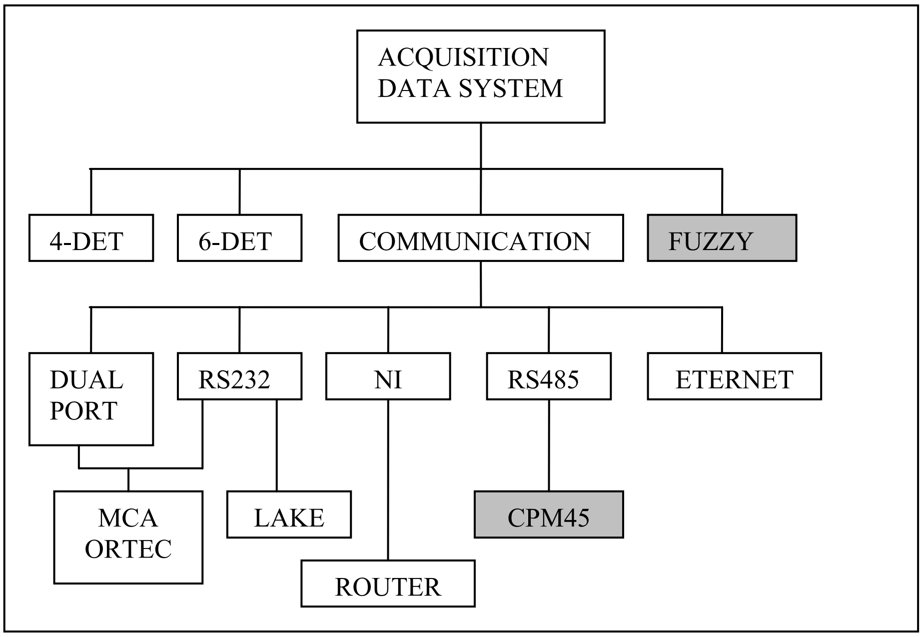


Figure 7. Simplified diagram of the data acquisition system. The grey colored blocks indicate the classes developed in this work.

CPM45
+ic: hexa +oc: hexa -CRCTable[ ]: hexa -commaImp: string -commaOut: string
-analy(ic, CRCTable): string -conve(hexa,string): hexa

FUZZY
-DTemp: number +Temp: number +Fpow: number -fuzzyTemp[ ] -fuzzyDtemp[ ] -tpf: string -tpi: string -tpfv: number -tpiv: number
+manager( ) -temperature( ) -value( ): number -power( ): string -desfuPower( ): number -calcDtemp( ): number

Figure 8. Representation diagram of classes developed.

5. CONCLUSIONS

This work presents the sample heating system including a small graphite furnace which operates in the range of room to 1200 ^{o}C. Because of the particular design aspects of the furnace (mechanical and electrical) it was necessary to make a study its behavior to determine the pertinence fuzzy variables and define the fuzzification and defuzzyfication rules, which were simulated in the MatLab program as an EXCEL file as well as in the Visual Basic program written for this purpose.

Finally, the project of the class CPM45 and FUZZY was developed and it is being incorporated into data acquisition system of the Hyperfine Interactions Laboratory at IPEN.

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