

# Fuzzy Logic Temperature Control System For The Induction Furnace

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**Abstract:** This research paper describes the fuzzy logic temperature control system of the induction furnace. Temperature requirement of the heating system varies during the heating process. In the conventional control schemes, the switching losses increase with the change in the load. A closed loop control is required to have a smooth control on the system. In this system, pulse width modulation based power control scheme for the induction heating system is developed using the fuzzy logic controller. The induction furnace requires a good voltage regulation to have efficient response. The controller controls the temperature depending upon weight of meat, water and time. This control system is implemented in hardware system using microcontroller. Here the fuzzy logic controller is designed and simulated in MATLAB to get the desire condition.

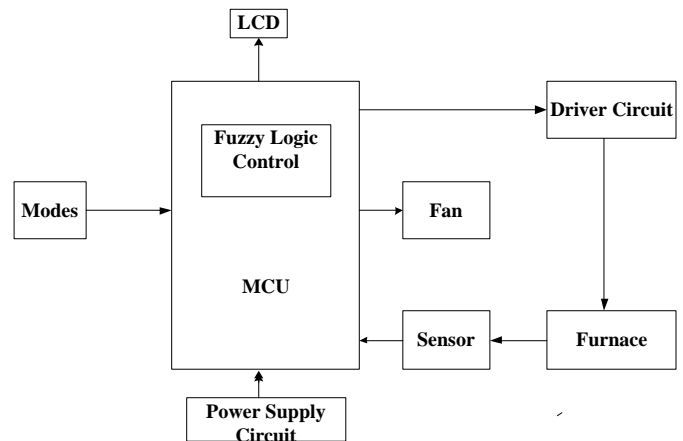
**Keywords:** Induction Heating, Fuzzy Logic, Temperature Control, Microcontroller, MATLAB

## I. Introduction

Nowadays, many different technologies are used to design electric furnaces. Electric furnaces are widely used in many industrial applications like steel melting, brazing, hardening and domestic applications. The major control parameters of the furnace are temperature and time. Generally, control of temperature and time can be realized in two way; either using analogue designs and digital designs[1]. Analogue designs generally make use of simple timers and thermostate to regulate the time and temperature respectively where as digital designs make use of components such as microcontroller, sensors and integrated circuits etc. The operating frequencies must be selected for these applications. Induction furnace has become popular because of its advantages such as cleanliness, low wastage of heat and safety. Different control methods can be used to vary the output temperature. The output power can be controlled by varying the switching frequency using pulse frequency modulation technique (PFM)[3]. The phase shift control technique varies the output power by phase shifting the pulse[3]. The above switching methods have the switching losses depending upon the load changes. Fuzzy logic control techniques are widely used in several fields. This system decreases the switching losses of the heating system and suitable for various power setting. It can be approached by software only, hardware only or the combination of software and hardware.

## II. System Block Diagram

The block diagram of the induction furnace as shown in figure-1. This system approaches Fuzzy logic temperature control using MATLAB Simulink. In this system power supply circuit is used to give the desire electrical signal to the microcontroller. Microcontroller controls the whole process. Modes and LCD display are used as the user interface. Driver circuit is used to drive the heating system of the furnace. Temperature sensor is used to sense the temperature of the furnace. Microcontroller controls the temperature according to the result of the comparison between set temperature and real temperature. Fan is used to reduce the heat of the furnace. The fuzzy logic controller uses the meat, water and time as the input and the temperature is used as output to maintain required temperature and to minimize the switching losses of the heating system.



**Fig1:** System Block Diagram of the induction Furnace

The flowchart shown in Fig.2 is for the operation of the system. Firstly the microcontroller will initialize input/output ports and read the modes. If the condition of meat mode is between 0 and 0.5Kg, the condition of water mode is between 0 and 0.4 Litre and the condition of time mode is between 10 and 30 minutes, the range of temperature is between 180°C and 250°C. If the input modes are not in this range, check the next conditions. In this way, the input conditions are checked step by step. And then the temperature of the heater is calculated and generates required phase angle. If the read temperature is greater than ten time of the calculated temperature, decreases the phase control. If not, increases the phase control. The microcontroller adjusts the phase of the TRIAC to reach the desire condition and display in LCD. If the working time is completed, the system will be stopped.

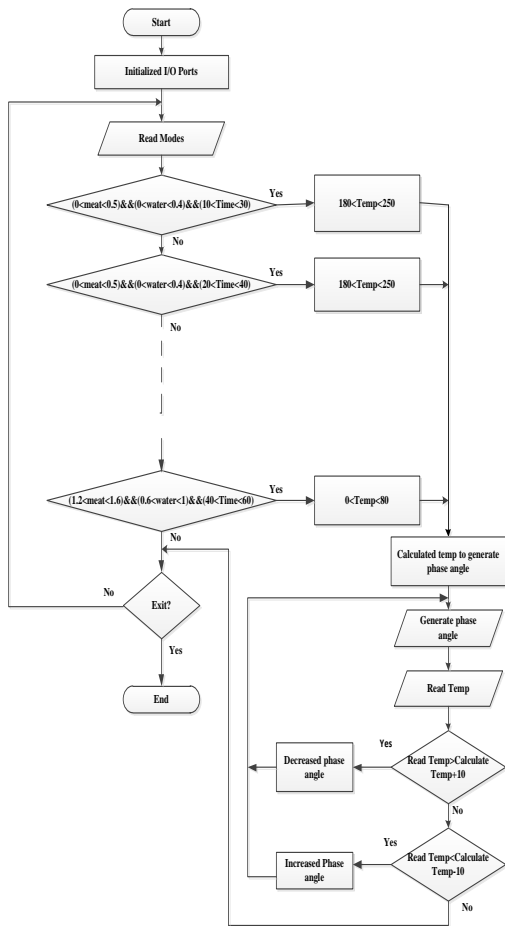


Fig 2: Flowchart of the system.

Table 1: Rule Base

Time		VS	S	L	VL
Meat					
Water					
S	L	VH	H	M	L
S	M	VH	H	M	L
S	H	VH	H	M	L
S	VH	VH	H	M	L
M	L	VH	H	M	L
M	M	VH	H	M	L
M	H	VH	H	M	L
M	VH	VH	H	M	L
L	L	VH	H	M	L
L	M	VH	H	M	L
L	H	VH	H	M	L
L	VH	VH	H	M	L
VL	L	VH	H	M	L
VL	M	VH	H	M	L
VL	H	VH	H	M	L
VL	VH	VH	H	M	L

III. Implementation

A. Implementation using MATLAB

In this paper fuzzy control algorithm is used to control the temperature of the furnace according to the time requirement. Fig 3 shows the FIS Editor of the induction furnace. The membership functions for the weight of meat are defined as Small, Medium, Large, Very Large and the membership function for water are defined as Low, Medium, High, Very High while the membership functions for time are defined as Very Short, Short, Long, Very Long. Then, the output membership functions for time are defined as Low, Medium, High, Very High. The weight of meat and water are measured in kilogram(kg) and Litre(L). The time taken and output temperature are defined as minutes and degree celsius. Table 1 shows the rule base of the induction furnace.

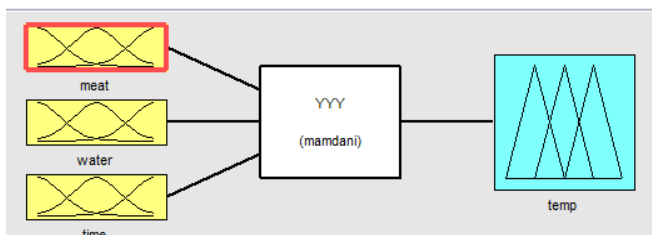


Fig 3. FIS Editor of fuzzy logic controller for Induction Furnace

A fuzzy control system consists of three main parts (1) Fuzzification (2) Rule Base and Inference Engine (3) Defuzzification

(1) Fuzzification

Fuzzification is the process of changing a real scalar value into a fuzzy value.

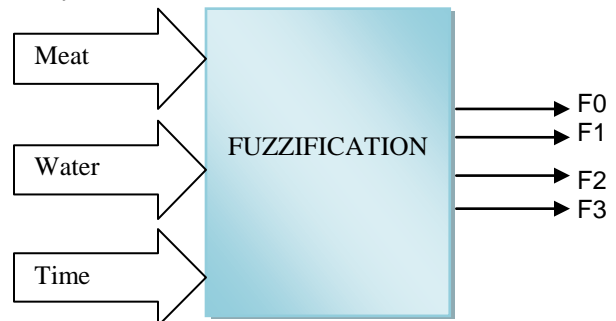


Fig 4: Fuzzification Block

**Table 2: Result of Fuzzification**

Input Variables	Input Values	Range	Fuzzification Value
Meat	0.5	$(0.4 < x < 0.9)$	$F0 = (0.5 - 0.4) / (0.65 - 0.4) = 0.4$
Water	0.3	$(0 < x < 0.4)$ $(0.2 < x < 0.6)$	$F1 = (0.4 - 0.3) / (0.4 - 0.2) = 0.5$ $F2 = (0.3 - 0.2) / (0.4 - 0.2) = 0.5$
Time	40	$(30 < x < 50)$	$F3 = (50 - 40) / (50 - 40) = 1$

**(2) Inference Engine**

Inference engine receives the input values from the fuzzification process and uses the Max-Min Composition-method.

$$R1 = \min\{F0, F1, F3\} = \min\{0.4, 0.5, 1\} = 0.4$$

$$R2 = \min\{F0, F2, F3\} = \min\{0.4, 0.5, 1\} = 0.4$$

$$R = \max\{R1, R2\} = 0.4$$

**(2) Rule Based**

Rule\_based is a set of "if-then" statement and determines how the fuzzy logic operations are performed with the knowledge based.

**Table 3: Rules for Applied Modes**

Rule No	Inputs			Output
	Meat	Water	Time	Temperature
1	Medium	Low	Long	Medium
2	Medium	Medium	Long	Medium

**(3) Defuzzification**

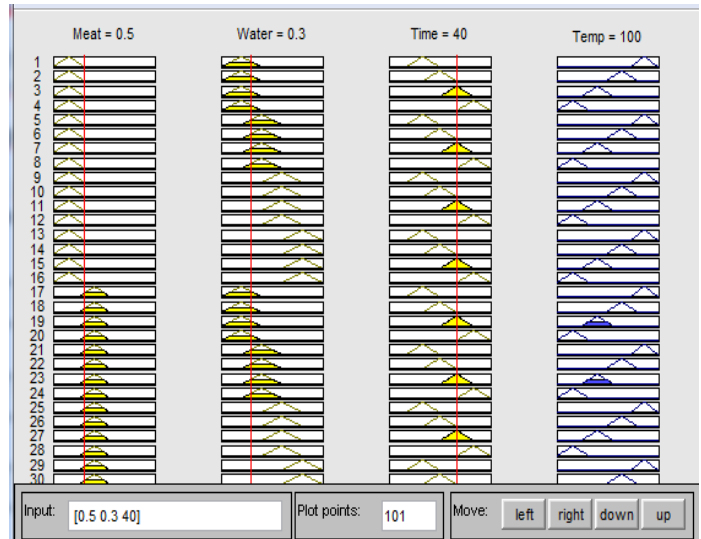
Defuzzification is the process of converting fuzzy set description of an action into a crisp value.

$$\sum R = 0.4$$

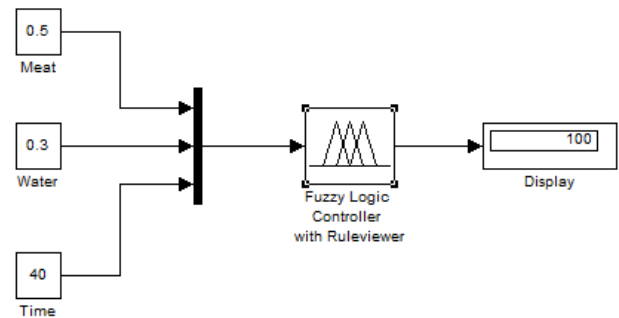
$$\sum R * Z = (0.4 * 100) = 40$$

$$\sum R * Z / \sum R = 40 / 0.4 = 100$$

The result of rule viewer for the fuzzy logic based-induction furnace as shown in fig-5. For the temperature control system, the three inputs: meat, water, time are 0.5, 0.3 and 40 respectively. So, the output temperature 100 degree Celsius means Medium condition.

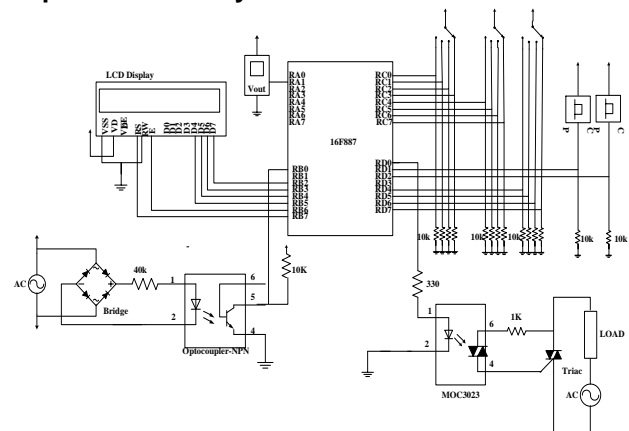


**Fig-5: Rule Viewer of FLC for induction furnace**



**Fig-6: Checking with MATLAB command box for FLC**

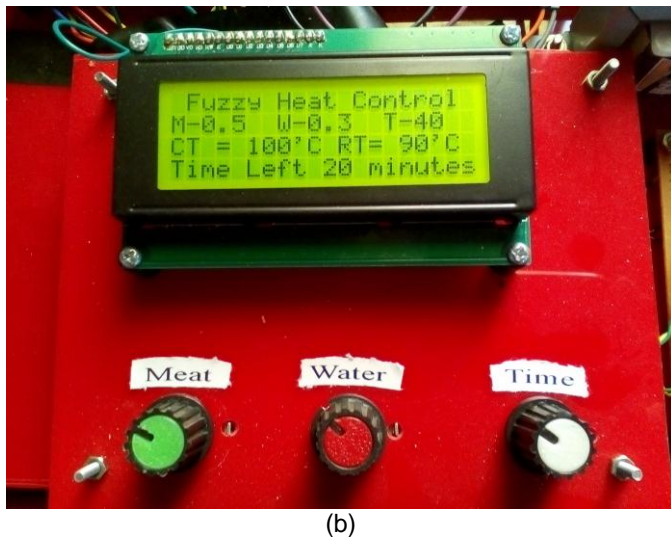
**B. Implementation By Hardware**



**Fig-7: Overall Circuit Diagram of the system**

- i. **Microcontroller Unit:** Microcontroller unit is the main of the system. To keep the desired temperature, it takes feedback from the furnace. LCD is connected with the output ports of the Microcontroller. Selecting modes have been connected with the input ports of the Microcontroller. Moreover, start and stop switches are used in this system. After choosing the selecting modes, the start switch is pressed to work the system. After finishing the working principle, the stop switch is pressed.





**Fig-13:** (a) Testing the condition of the zero crossing and phase angle control system of the induction furnace (b) Display the condition of the 40 minutes timer

#### IV. Discussion

In this phase angle control system, a gate pulse is sent to the Triac. This gate pulse generates between the zero crossing points. If the pulse is not generated after zero crossing, the Triac will be off and the current can't flow through it. ON time of the Triac is determined by the delay time between the zero crossing and gate signal of the Triac. After occurring the zero crossing a small delay time is present before the firing of the triac. Moreover, the delay time can be changed by reading the ADC values. So that the Triac is fired depend upon the read value. There is a small difference temperature in hardware system depend upon the distance between the temperature sensor and heater.

#### V. Conclusion

The temperature control system of the induction furnace is effectively achieved by using MATLAB software. Hardware system is designed with the Microcontroller. Since the system based on fuzzy logic control, the system is more reliable and the cooking time can adjust as we need. So, this system is very useful for user. The whole system is based on the fuzzy logic control. FIS editor of MATLAB fuzzy logic controller is used to obtain the rule viewer.

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