Fuzzy Logic Approach for Boiler Temperature & Water Level Control

Anabik Shome, Dr. S.Denis Ashok

Abstract— Boiler is the main component in generating steam in thermal power generation units and its control is very important in many applications. In present situation conventional PID control is being used for this purpose. These conventional controllers in power plants are not very stable when there are fluctuations and, in particular, there is an emergency occurring. Continuous processes in power plant and power station are complex systems characterized by nonlinearity, uncertainty and load disturbances. The conventional controllers do not work accurately in a system having nonlinearity in it. So, an intelligent control using fuzzy logic is developed to meet the nonlinearity of the system for accurate control of the boiler steam temperature and water level.

Index Terms— Boiler temperature control, Conventional controllers, Fuzzy logic, Fuzzy logic control, Fuzzy Inference System, Microcontroller, PID control, Water level control.

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1 Introduction

Temperature controllers are needed in any situation requiring a given temperature be kept stable. This can be in a situation where an object is required to be heated, cooled or both and to remain at the target temperature (set point), regardless of the changing environment around it. Temperature controllers are used in a wide variety of industries to manage manufacturing processes or operations.

There are several reasons for using automatic temperature controls for steam applications.For some processes, it is necessary to control the product temperature to within fairly close limits to avoid the product or material being processed being spoilt.Steam flashing from boiling tanks is a nuisance that not only produces unpleasant environmental conditions, but can also damage the fabric of the building. Automatic temperature controls can keep hot tanks just below boiling temperature. Also for economy, quality and consistency of production, saving in manpower, comfort control, safety and to optimize rates of production in industrial processes boiler temperature control is necessary.

Conventional control system in power station adopts PID controller. Unfortunately, large inertia and lag appear, when we use PID controller which could not adjust the temperature to good scope. On the other hand, drawbacks of this system are terrible robustness and fixed PID parameter which could not regulate with variation of the object. Because there are nonlinearity, variation, disturbance and change of objective architecture, the system could not attain well result by using PID parameter which previously set.

Since the introduction of fuzzy set theory by Zadeh and the first invention of a fuzzy controller by Mamadani, fuzzy control has gained a wide acceptance, due to the closeness of inference logic to human thinking, and has found applications in some power plants and power systems. It provides an effective means of converting the expert-type control knowledge into an automatic control strategy. A fuzzy control mainly simulates control experience of human and gets rid of control object. It discusses definite nature, fuzzy and imprecise information system control in the real world.

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2 Current Scenario of Boiler Control

In electric boilers, the resistance of the water to the passage of electricity generates heat and steam. No part of the generator is ever hotter than the water or steam itself. Therefore, no baking of solids or residue occurs. Furthermore, when the electrode tips become uncovered, no current can pass, hence, no low water damage can occur. Within the pressure vessel of the generator, a cylinder, open at the bottom, is welded to the inside of the upper-head of a pressure vessel. This cylinder divides the vessel into two concentric chambers. The outer chamber (K) is the regulating chamber. The inner chamber (J) is the generating chamber. Suspended within the generating chamber are the electrodes (N). Electric power (P) is easily connected to the three electrode terminals. A prescribed quantity of Electrolyte is dissolved in water and poured into the generator through the hand fill (G). This Electrolyte remains in the generator until drawn off with the water through the drain valve (M). Electric power is turned on, and heat is generated by the resistance of the water to the passage of current between the solid electrodes. Steam produced in the generating chamber (J) flows through the steam valve outlet (I), and via the steam header (E), through the pressure regulating valve or(C) to the regulating chamber (K). Before the electric boiler is turned on, water levels would be balanced. Adjusting the screw on the pressure regulator valve (D) sets the desired pressure. When the system is turned on, air is automatically exhausted through the air eliminator (A), which closes when heated by the steam. If the steam consumed is less than maxi-

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mum, pressure built-up in the generator chamber until it reaches the pressure limit set by the pressure regulator. At this point the pressure regulator valve partially closes, reducing the amount of steam entering the regulating chamber. This unbalances the system momentarily, permitting the water to rise in the regulating chamber due to the higher pressure condition in the generating chamber. As the water level drops in the generating chamber the electrodes are progressively exposed, and the amount of steam being generated decreases. Inasmuch as current input is proportional to the immersed area of the electrodes, the falling water level reduces the electric input. Conversely, if heavy use of steam tends to lower the desired pressure, the regulating valve opens wide, allowing more steam into the regulating chamber. This forces water back into the generating chamber, increasing the flow of current and rate of steam production by completely enveloping the electrodes. The water level in both chambers is rarely balanced. This condition occurs only at full load.

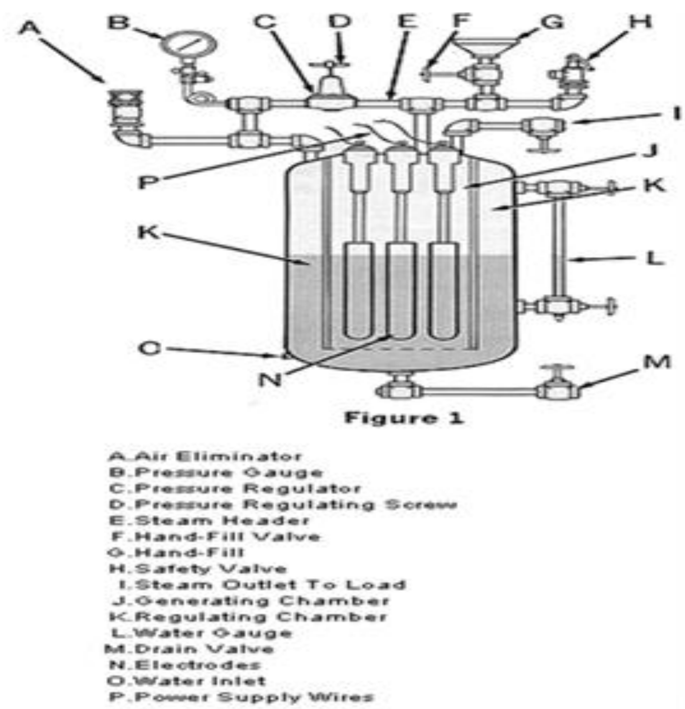

Fig.1. Conventional Boiler control

3 Proposed Methodology

The proposed method consists of two sections.First section is to develop a steam temperature monitoring and control system and the second section consists of water level control.For both of the sections Fuzzy Logic Control will be used.

A microcontroller will be programmed with the fuzzy knowledge base rule. The temperature sensor will be interfaced with the microcontroller to monitor the steam temperature and a level indicator circuit will be interfaced with the microcontroller which will indicate the water level inside the boiler chamber.The microcontroller will take the temperature sensor output and level indicator output as the two inputs for the Fuzzy Inference System.After fuzzification of the inputs and applying suitable rules and defuzzifying the output the microcontroller generates appropriate control signals.

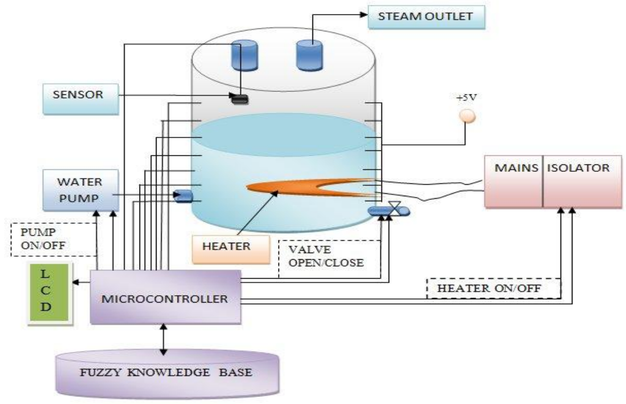

Fig.2. Proposed FLC based boiler control

3.1 Temperature Monitoring & Control

3.1.1 Temperature Monitoring

- The temperature is measured using the sensor.
- The sensor output is compared with the set value.
- The error or deviation from the set value is given as an input to the fuzzy logic control system.

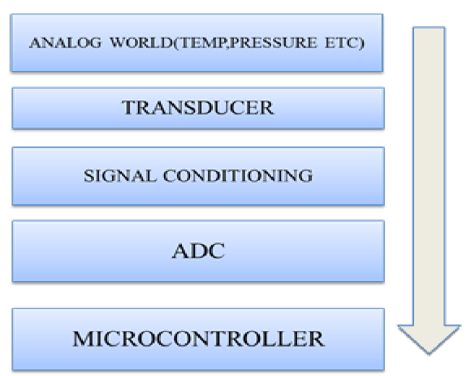

Fig.3. Interfacing of sensor with microcontroller

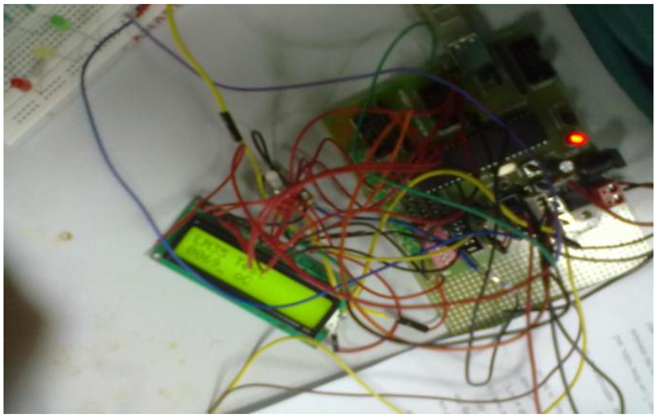

Fig.4. Setup for temperature monitoring

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3.1.2 Temperature Control

- The Fuzzy Inference system fuzzifies the inputs and applies suitable rules and calculates the defuzzified value.
- It then decides the suitable control action to be performed.
- The microcontroller gives command to perform the required control action to turn the heater ON/OFF for safe operation of the boiler.

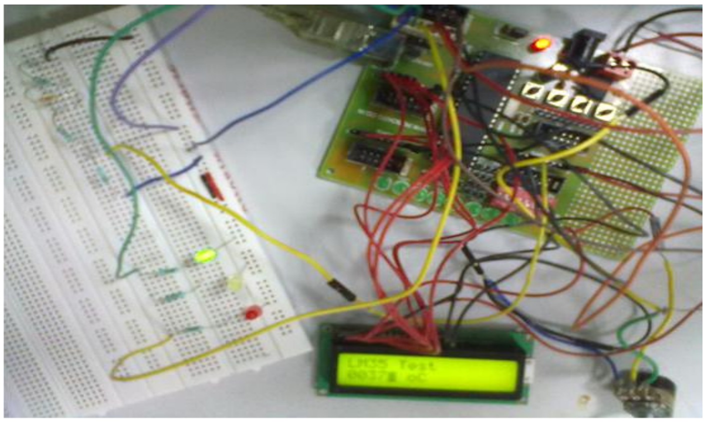

Fig.5. Setup for Temperature control

3.2 Level Control

The water level control is also an important parameter for boiler control.The water level inside the boiler chamber needs to be controlled because of changing load demand.When there is a need of more steam water level should be high and when there is a need of less steam the water level should be low.To maintain the water level inside the boiler chamber a level indicator circuit is used and the circuit is interfaced with the microcontroller.The Fuzzy Inference System stored inside the microcontroller then fuzzifies the inputs and applies suitable rules and then gives the defuzzified values which is then processed by the microcontroller to give the suitable control action to turn ON/OFF the inlet pump and OPEN/CLOSE the outlet valve.

4 Fuzzy Inference System

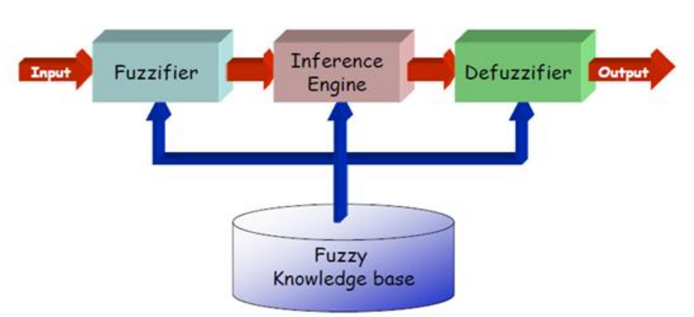

Fig.6. Block diagram of fuzzy inference system

INPUTS	
NEG=Negative	VS=Very Small
ZE=Zero	S=Small
VS=Very Small	M=Medium
S=Small	Hi=High
M=Medium/Moderate	
H=High	

OUTPUTS	
HTRMAX=Heater Maximum	PONVCLOSED=Pump On Valve Closed
HTRMOD=Heater Moderate	PONVOPENLESS=Pump On Valve Open less
HTROFF=Heater Off	POFFVOPENFULL=Pump Off Valve Open Full

Fig.7. Input/Output Fuzzy Interpretetions

Fuzzy rules:

1. If (STEAMTEMP is NEG) then (HEATER is HTRMAX) (1)
2. If (STEAMTEMP is ZE) then (HEATER is HTRMAX) (1)
3. If (STEAMTEMP is VL) then (HEATER is HTRMAX) (1)
4. If (STEAMTEMP is L) then (HEATER is HTRMAX) (1)
5. If (STEAMTEMP is N) then (HEATER is HTRMOD) (1)
6. If (STEAMTEMP is H) then (HEATER is HTROFF) (1)
7. If (WATERLEVEL is VS) then (PUMPANDVALVE is PUMPONVALVEOFF) (1)
8. If (WATERLEVEL is S) then (PUMPANDVALVE is PUMPONVALVEOFF) (1)
9. If (WATERLEVEL is M) then (PUMPANDVALVE is PUMPONVALVEOFF) (1)
10. If (WATERLEVEL is HI) then (PUMPANDVALVE is PUMPOFFVALVEOPEN) (1)

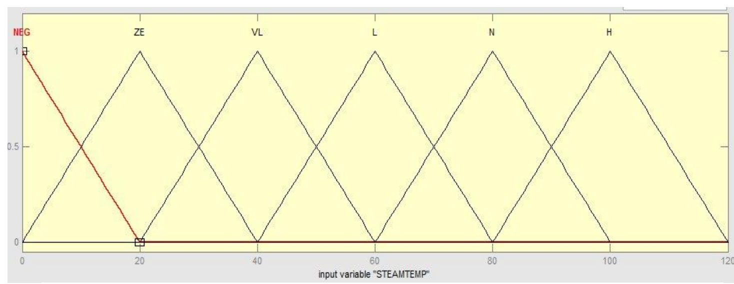

Fig.8. Input Membership function: STEAMTEMP

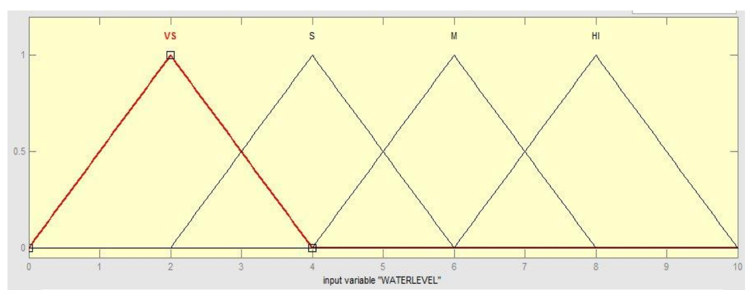

Fig.9. Input Membership function: WATERLEVEL

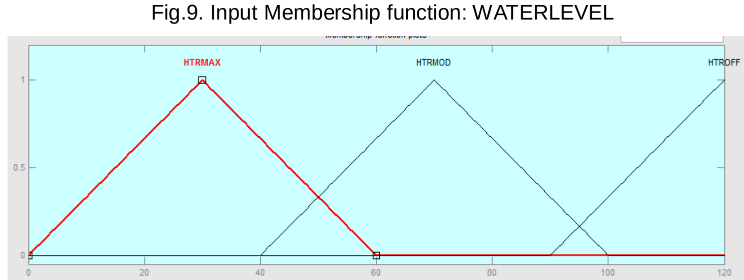

Fig.10. Output Membership function: HEATER

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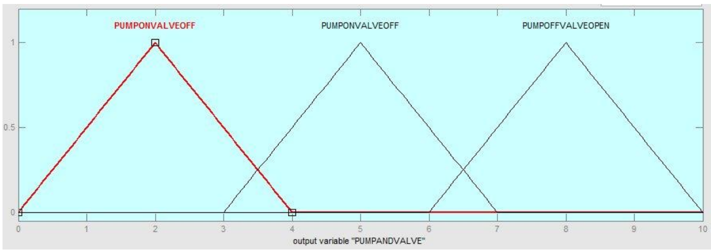

Fig.11. Output Membership function: PUMPANDVALVE

5 RESULTS

The fuzzy control model for boiler temperature and water level control is simulated using MATLAB and also verified using C-Program.The steam temperature monitoring & control portion is also verified using a prototype model.The level control portion is verified using MATLAB and C-Program but not verified experimentally due to some hardware limitations.

5.1 MATLAB Simulated Results

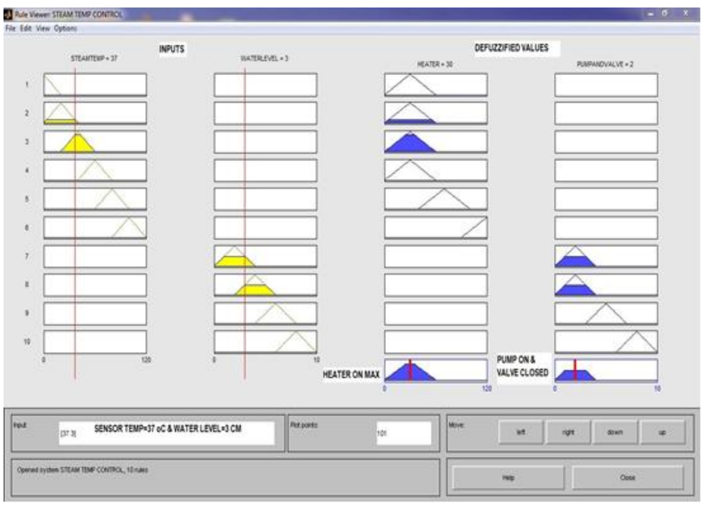

Fig.12. MATLAB simulated output when Steam temp=37^{O}C and Water level=3cm

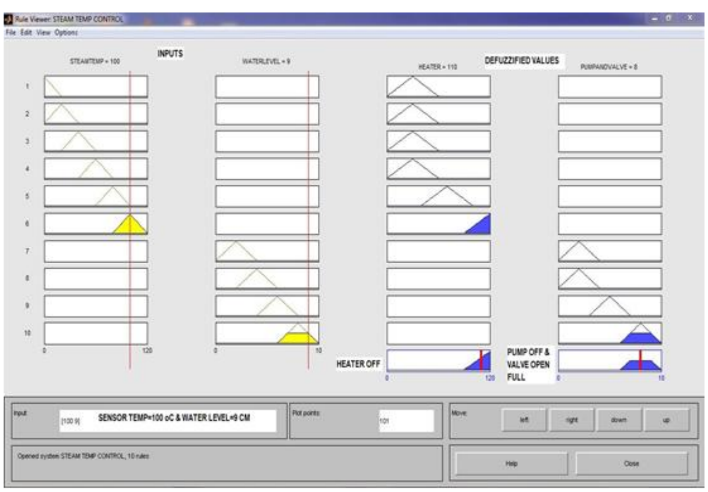

Fig.13. MATLAB simulated output when Steam temp=100^{O}C and Water level=9cm

5.2 C-Program Simulated results

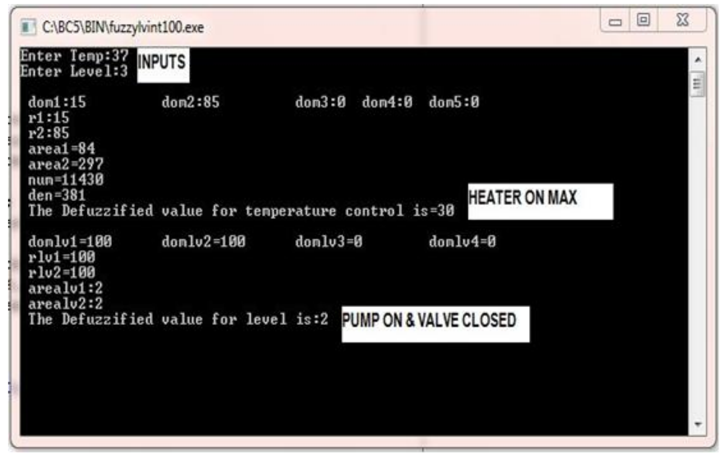

Fig.14. C-Program simulated output when Steam temp=37^{O}C and Water level=3cm

Fig.15. C-Program simulated output when Steam temp=100^{O}C and Water level=9cm

5.3 Experimentally Verified Results for Steam Temperature Monitoring & Control

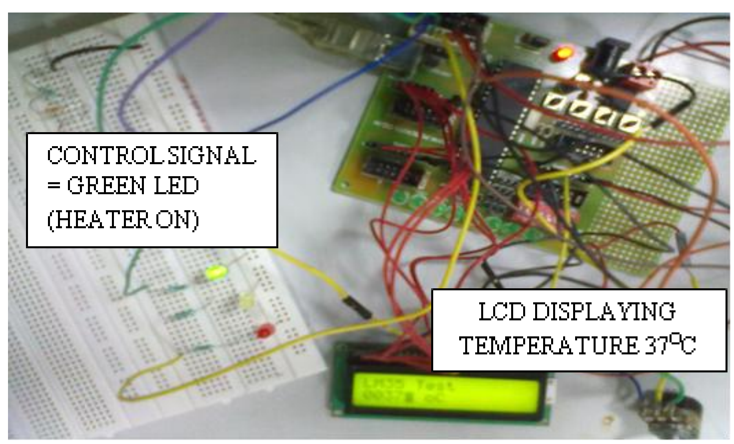

Fig.16. LCD displaying temp=37^{O}C & Green LED corresponds Heater ON with Maximum Intensity

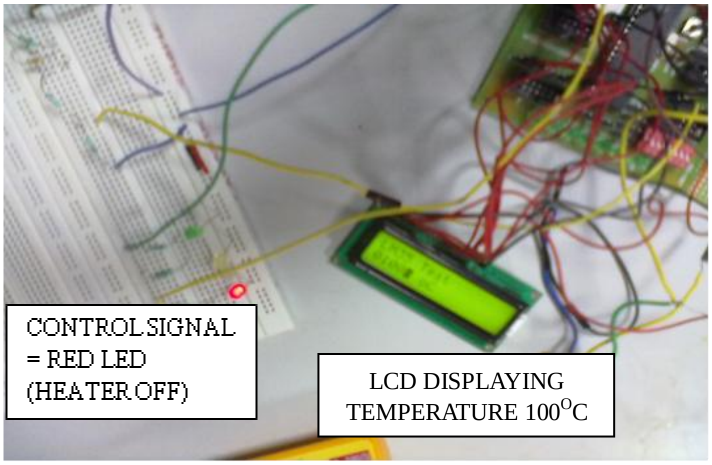

Fig.17. LCD displaying temp=100^{O}C & Red LED corresponds Heater OFF.

5.4 Discussion about the Result

From the above displayed figures we can observe that the temperature monitoring & control portion as well as the level control portion is simulated successfully in MATLAB and also using C-Program.The temperature monitoring & control portion is also experimentally verified using a prototype model.

6 Conclusion

The fuzzy logic based boiler temperature monitoring & control and Water level control inside the boiler chamber is simulated successfully and also the temperature monitoring & control portion is experimented successfully using a prototype model and the results are also verified verified.So, we can conclude that the fuzzy logic based boiler temperature and level control is working properly and the results obtained are very promising and satisfactory.

7 Future Scopes

Fuzzy logic is a very emerging intelligent control method which can be applied successfully in nonlinear as well as in linear systems. Till now the conventional controllers like PID controllers are used in boiler temperature control applications but it has some disadvantages and errors when there is variation of load and nonlinearity arises in the system. But intelligent control system like fuzzy control works efficiently under these environments and can be easily implemented as observed in the experiment performed on the prototype model and using more ranged temperature sensors and level indicators and more powerful microcontrollers it can be implemented easily in industrial boiler and other steam temperature control applications as well as in other temperature and water level control applications.

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