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Embedded Fuzzy Module for Sugar Industrial Boiler Parameter Control

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Abstract*— In sugar industry, past the sugar was main product and bagasse was considered as west and its disposal was the problem. The present paper highlights the design and development of Embedded Fuzzy Module for energy efficiency improvement of bagasse boiler for a sugar factory intended for cogeneration system. The multipurpose boiler considered parameters are Water flow, Steam flow, Amount of fuel and Air flow. The Fuzzy Logic Inference is to find out the desirable amount of fuel (bagasse) and Air flow for targeted steam flow. In this paper Embedded Fuzzy Logic Module for improving the steam generation performance as well as saving fuel of boiler in the sugar industry.

***Index Terms* — Boiler parameters, Control system, Fuzzy Logic, Sugar industry etc.**

I. INTRODUCTION

The sugar industry is India's second largest agro processing industry. Now a day the Sugar Industry expected to be self-sufficient in respect to the energy. In past the sugar was the main product and bagasse was considered as factory waste and its disposal was the problem. With the cost of fuel increasing day by day then need of improving boiler efficiency becomes a subtle task. Presently the bagasse is mainly used to generate electricity as an energy cogeneration. The present paper highlights the design and development of *Embedded Fuzzy Module* for energy efficiency improvement of bagasse boiler for a sugar factory intended for cogeneration system. The multipurpose boiler employed in the Sugar Factory generates products like *Heat, Steam, and Gasses* etc. The generated steam by boiler otherwise going waste is used for electricity generation purposes. We propose an *Embedded Fuzzy Module* that helps the utilization of steam for Electric power generation with the improved efficiency. *Amount of air* blown in, supply of *biofuel*, *quantity of water* and steam outlet form the control parameters of a boiler. These parameters are interdependent of one another. *B. Hemalathaet al* [1] proposed a dynamic behavior of the drum and water level of the boiler controlled by PID controller. They have developed mathematical model and studied various responses of the system *N. Magasiner et al* introduced a control parameter of the boiler and their effect using labview [2]. *Yonghong Huanget al* [3] proposed a new advanced genetic adaptive control strategy for drum level regulation. They introduced the self-tuned parameters as a novel genetic adaptive mechanism using MATLAB.

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Fuzzy logic is the method of enhancement in the knowledge base reasoning process. It is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth. FLC (Fuzzy Logic Control) is capable of successfully handling the system with non-linearities and various complexities without having to develop their mathematical models. Fuzzy logic is a rule base system. Rules are in *IF-THEN* format. As a rule-based Fuzzy approach involves incorporating human Expertise on how to control a system in terms of a set of rules. Complex processes can often be controlled by relatively few *Fuzzy Rules*. It allows a more understandable controller design and faster computation for real time applications. In fuzzy logic there are a number of applications like Storage of biomedical product at a particular temperature, Robotics, Home appliances control, AC control, Industrial Automation, Power Control System etc. [4]. Do date many Researchers have attempted to employ Fuzzy Logic in the control of power generation in the sugar industry driven by Boiler Energy. The performance of FLC is better than the conventional PID controller [5]. The *Embedded Fuzzy Hardware* is a single chip solution of the control system accommodating the control variables. It could be very compact, simple and reliable solution for implementation of FLC for target application. The basic process of Embedded Fuzzy Control (EFC) is to develop embedded fuzzy program in Micro 'c' software and burn into the PIC (Peripheral Interface Controller) microcontroller with the help of PICPgm programmer. The basic aim of this paper is to design an embedded solution for increasing the efficiency of boiler performance to be used for power generation plant in the sugar industry. The block diagram of overall system is shown in fig.1 (a).

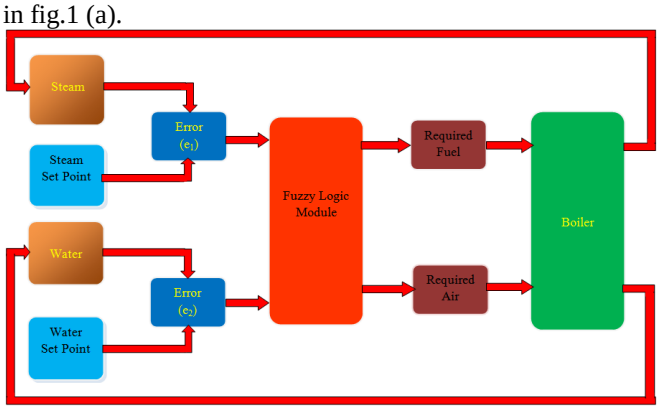

Figure 1: (a) Block diagram of overall implementation

The aim of this paper is to create a *Fuzzy Logic Module* for improving the steam generation performance of boiler in the sugar industry. The steam flow and water flow signal are the input parameters of the system.

The present steam flow and set point for desirable steam flow are given to the error computing block (e_1). The variation of present steam flow from set point pertaining to the steam demand forms the *Error (e_1)* that goes to the Fuzzy Logic Module. The Set-point circuit consists of resistor and Reset keys as depicted in fig.1 (b). The variation of present water flow from set point pertaining to the water demand is also given to the Fuzzy Logic Module entitled as *Error (e_2).* The overall fuzzy controlling process of Fuzzification, Fuzzy Inference and Defuzzification are embedded in the PIC microcontroller. The job of Fuzzy Logic Inference is to find out the desirable amount of fuel (bagasse) and Air flow for targeted steam flow. The hardware implementation of proposed paper is shown in fig.1 (b).

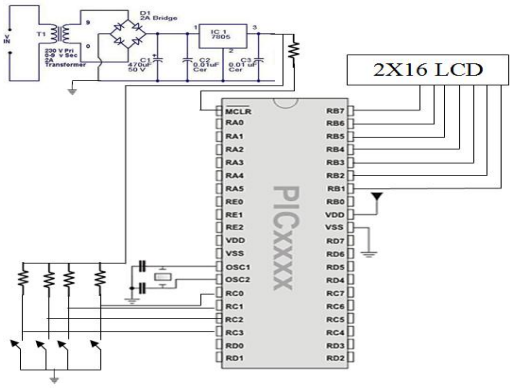

Figure 1: (b) Hardware Implementation

II. PIC PROGRAM FLOW

The Fuzzy Logic based control strategy has been outlined in the PIC program flow shown in fig. 2.

III. FUZZIFICATION

Fuzzification means the conversion of crisp value into fuzzy membership function. Crisp value is nothing but the present water flow and steam error signal. The Fuzzification of *Error (e_1)* and *Error (e_2)* are via triangular membership function is depicted in the figures 3(a) and 3(b).

A. *Error (e_1) Signal*

Error (e_1) signal is the difference between set-point and present water flow signal. The Universe of Discourse (UoD) for error (e_1) signal is -200 to 200 and partitioned into three regions viz. *low, medium and high* shown in fig 3(a).

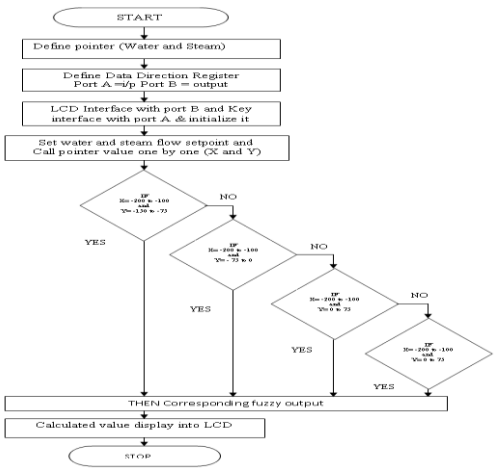

Figure 2: Program flow chart of PIC microcontroller

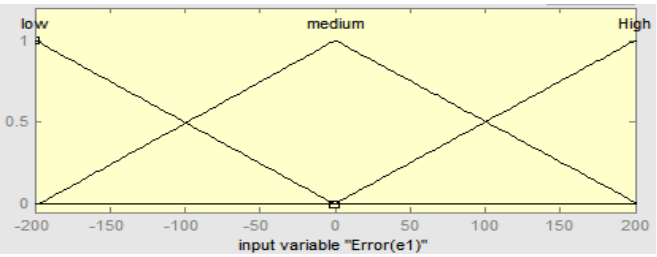

Figure 3: (a) input membership function for Water error (e_1)

B. *Error (e_2) Signal*

Error (e_2) signal is the difference between set-point and present steam flow. The Universe of Discourse (UoD) for *error (e_2)* signal is -150 to 150 and partitioned into three regions viz. *decrease, maintain and increase* shown in fig 3(b).

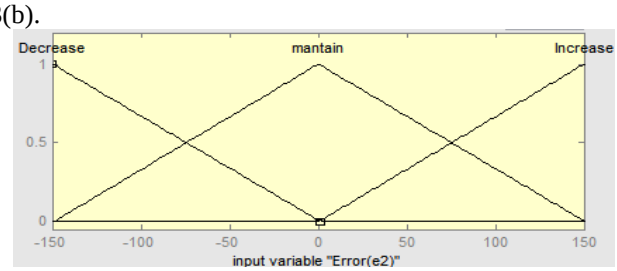

Figure 3: (b) input membership function for Steam error (e_2)

IV. DEFUZZIFICATION

Defuzzification means the conversion of membership function into Crisp value. Crisp value is nothing but the amount of fuel and Air flow. Fuel and Air are the output variables of the *Fuzzy Logic Module*.

A. *Fuel signal*

Amount of Fuel is the first output variable. The UoD of fuel is 0 to 600 partitioned in to three regions and entitled as *minimum, maintain and maximum* shown in fig. 4(a).

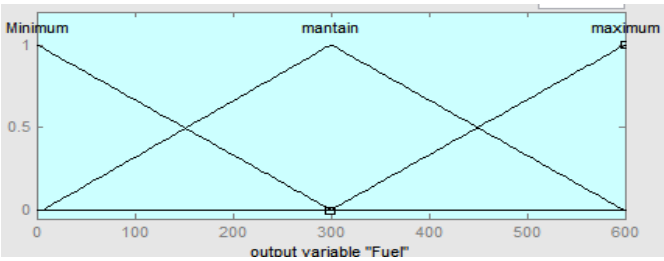

Figure 4: (a) Output membership function for required Fuel

B. *Air flow*

Air flow signal is Second output signal of the system. The range of fuel is 0 to 600 partitioned in to three regions and entitled as *slow, medium and fast* as shown in fig. 4(b).

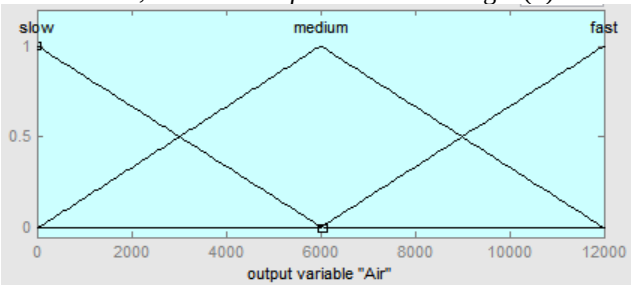

Figure 4: (b) Output membership function for Required Air

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V. FUZZY RULE

The logical inference is incorporated in *Fuzzy Logic Module* in the form of *IF-THEN* fuzzy rules as shown in above fig.5 (a). The *Fuzzy Inference System* is many types but present paper we use Mamdani's direct method. The fuzzy rules are shown bellow,

R_1: IF Water is Low and Steam is Decrease THEN Fuel is Minimum Air is Slow
R_2: IF Water is Low and Steam is Maintain THEN Fuel is Maintain Air is Slow
R_3: IF Water is Low and Steam is Increase THEN Fuel is Maximum Air is Medium
R_4: IF Water is Medium and Steam is Decrease THEN Fuel is Minimum Air is Slow
R_5: IF Water is Medium and Steam is Maintain THEN Fuel is Maintain Air is Medium
R_6: IF Water is Medium and Steam is Increase THEN Fuel is Maximum Air is Medium
R_7: IF Water is High and Steam is Decrease THEN Fuel is Maximum Air is Fast
R_8: IF Water is High and Steam is Maintain THEN Fuel is Maintain Air is medium
R_9: IF Water is High and Steam is Increase THEN Fuel is Maximum Air is Fast

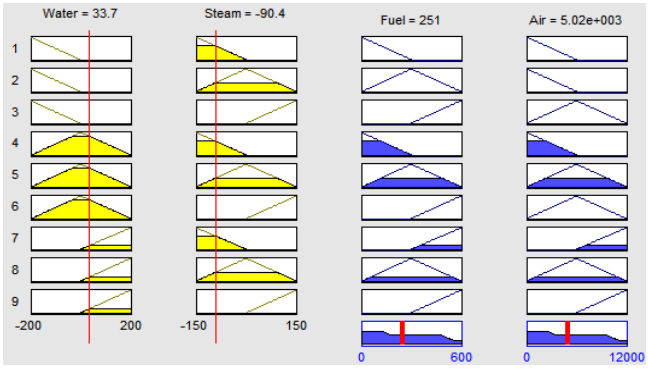

Figure 5: (a) Fuzzy Rule diagram

VI. SURFACE VIEW

Three dimensional view of fuzzy inference is shown in above fig 6.

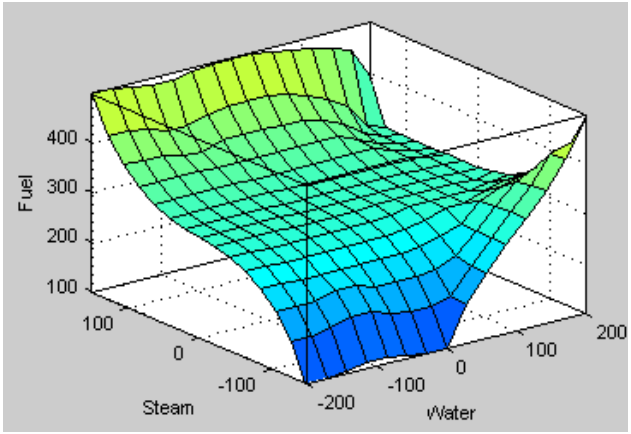

Figure 6: surface view of boiler from sugar industry

VII. SIMULATION

The Real PIC Simulator is simulation software targeted for PIC microcontroller. The hex files of program are called into Real PIC Simulator. Boiler parameter control program output is shown in fig 7.

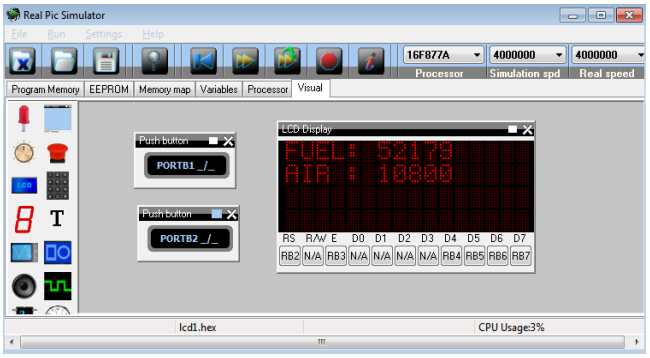

Figure 7: Simulation output of required air flow and Amount of fuel.

VIII. HARDWARE IMPLEMENTATION

The hardware implementation is shown in fig. 8.

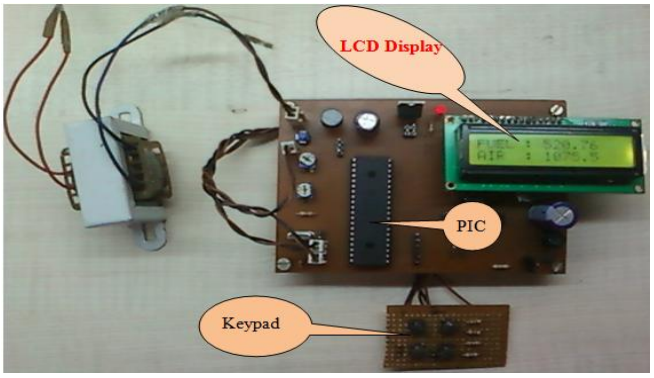

Figure 8: Hardware implementation

IX. RESULT AND CONCLUSION

A. *Fuel (bagasse)*

The objective of proposed paper was to design an *Embedded Fuzzy Logic Module* for improving the performance of power generation plant in sugar industry. The multipurpose boiler requires fuel as well as air for generating the steam with desirable pressure and maintain further. In power generation plant the steam is used for the driving the turbine system. fig. 9 (a) shows the air flow regulation with and without fuzzy. It is observed that control of air flow turned out to be smooth as compared to non-fuzzy control. The difference between required fuel without and with fuzzy is up to 9 quintals per hour. This amounts for saving of fuel.

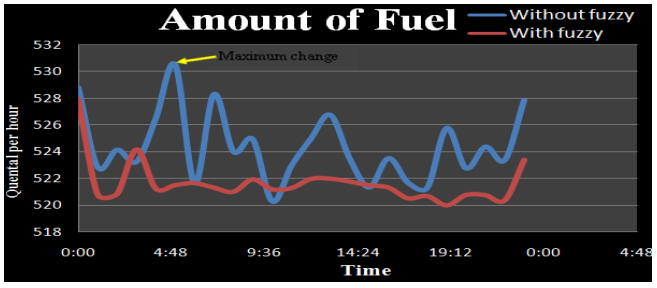

Figure 9: (a) Required amount of Fuel for boiler

B. Air flow

The percentage of required air flow depends on the amount fuel. The measurement unit is quintal per hour (QPH). With Fuzzy the required air flow is less as compare to without Fuzzy a shown in above fig 9.(b). *Embedded Fuzzy Logic Module* helps keep the environment pollution minimum by utilizing the less amount of fuel.

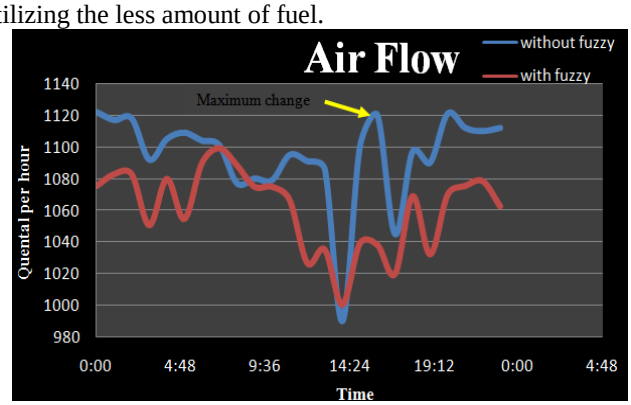

Figure 9: (b) Required Air flow for boiler

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