Fuzzy Logic Based Boiler Drum Level Control in Power Plant

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Abstract- Water level control is highly important in industrial applications. In this work a simple water level controller based on fuzzy logic is proposed. The fuzzy logic controller is based on Mamdani type Fuzzy Inference System. A boiler system is an integral component of a thermal power plant and control of water level in the drum of boiler system is a critical operational consideration for the drum water level control. The 3 element proportional integral derivative (PID) control is a popular conventional approach. This scheme works satisfactorily in the absence of any process disturbance. When there are significant process disturbances, the 3-element PID control scheme does not perform well because of lack of knowledge of proper controller gains to cope with such disturbances. FLC presents a model free approach that the performance of existing PID control scheme is observed and collected data is used to gain knowledge about the process. Based on this process knowledge, an intelligent control technique, fuzzy logic control is developed. This project shows that FLC gives better performance in rejecting process disturbance when compared to the 3 element PID control scheme.

Keywords–step down transformer, rectifier, voltage regulator, feed water control valve, optocoupler, filter, ADC.

I. INTRODUCTION

The boiler water/steam drum, or steam drum, is an integral part of the boiler's design. This vessel has three specific purposes; it provides a volume space to hold the boiling water in the boiler and enough water volume to allow for good thermal mixing of the cooler bottom drum water with the hotter surface interface water and provides surface area and volume for the efficient release of the entrained steam bubbles from the boiler water. The surface area and volume of the vapor space in the water/steam drum is critical to the efficient separation of the steam bubbles from the water. Too small an area can result in an excessive surface tension and high velocities, which result in wasted heat and drum water carry-over. Too large an area is simply a waste of materials and labor to construct the vessel. Low water levels affect the internal thermal recirculation of the boiler water resulting in cold spots in the boiler water and steam collapse. This lack of circulation also reduces the effectiveness of the chemical water treatment and can cause precipitation of the chemicals as chemical salts or foams. High water levels raise steam exit velocities and result in priming or boiler water carryover in to the distribution system. Priming results in wet dirty steam while carry-over can result in dangerous water hammer and pipe or equipment damage. A boiler is comprised of two basic systems. One system is the steam water system also called the waterside of the boiler. In the waterside, water is introduced and heated by transference through the water tubes, converted to steam, and leaves the system as steam. Boilers must maintain a chemical balance. The manner in which this is done can interact with the feed water control system. The amount of blow down must be considered in the feed water control scheme, especially if the blow down

is continuous. Often, the blow down flow is divided by the concentration ratio times the feed water flow. Continuous blow down is the common method for controlling the chemical concentration. On large boilers this may be done automatically by measuring the boiler water conductivity to control the blow down rate. The blow down rate may also be achieved by combining the conductivity with ratio control of blow down, rationing blow down to feed water flow.

II. PROPOSED ALGORITHM

Fuzzy logic control scheme is implemented into boiler drum level control system. Here drum level is maintained constant point, so this work implements the fuzzy logic control scheme.

Comparison between PID and Fuzzy scheme

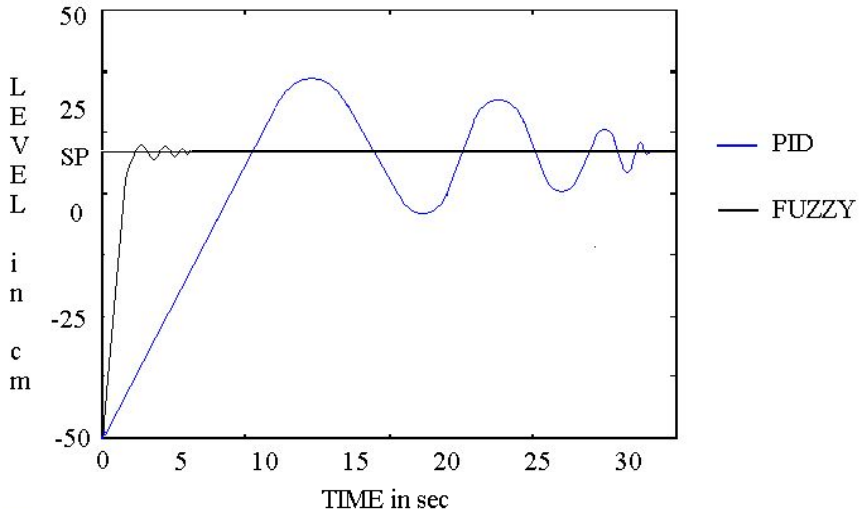


Figure 1 Comparison between PID and Fuzzy

Basics of Fuzzy Logic

Fuzzy Logic

Fuzzy logic is other class of artificial intelligence, but its history and applications are more recent than those of expert system. Human thinking doesn't always follow crisp YES/NO logic, but is often vague, qualitative, uncertain, imprecise or fuzzy in nature.

Fuzzy set

A fuzzy set can be defined mathematically by assigning to each possible individual in the universe of discourse, a value representing its grade of membership in the fuzzy set. This grand corresponds to the degree to which that individual is similar or compatible with the concept representing by the fuzzy set. In other words, fuzzy sets support a flexible sensing of membership of elements to a set.

Fuzzy set A, is said to be subset of B if

$$\mu A(x) \leq \mu B(x)$$

E.g. B=far & A=very far

$$\mu A(x) \leq \mu 2B(x)$$

Crisp set

Conventional or crisp set are binary. An element either belongs to set or doesn't.

{TRUE, FALSE} {1, 0}

Membership function

The linguistic variables are defined as fuzzy sets of fuzzy subsets. A membership function is a curve that defines how the values of a fuzzy variable in a certain region are mapped to a membership value μ (degree of membership) between 0 and 1. the fuzzy sets can have more sub divisions such as very very low, very low, low, medium, high, very high, very very high etc.,

III. EXPERIMENT AND RESULT

HARDWARE DESCRIPTION AND IMPLEMENTATION

Hardware components that are used such as differential pressure transmitter, relay, pneumatic valve actuator, boiler drum, ADC, interface, programmed computer, DAC, power supply unit, valve driving circuit.

Hardware Modular

Power supply

It is the power source unit, it can be produce 5V and 12V ranges. This power supply units are

- Step down transformer
- Rectifier
- Filter
- Voltage regulator

Step down Transformer

When AC 230V 50Hz supply is applied to the primary winding of the transformer. It can be step down into 230V to 18V ranges. The output voltage will be pickup by the secondary winding of the transformer. This step down voltage will be applied to rectifier section.

Rectifier

This is the full wave bridge type rectifier. Bridge is constructed by four diodes. It is used to convert from AC form into DC form. This Dc output is given to filter section.

Filter

This is the capacitive type filter. It can be filter AC ripples in output DC voltage. It can be avoid AC ripples.

Voltage Regulator

The voltage regulators place an important role in our power supply. Here positive voltage regulators are used in the power supply. It can be able to produce fixed voltage outputs.

Differential Pressure Transmitter

Differential Pressure Transmitter (DPT) is the level measuring sensor as well as transducer, it looks like manometer. It is compared between actual value and reference value, because generate the electrical signal

Calculation of DPT

$L_T = L_{AC}-L_{Re}-HP$

Where

L_T = Total level of the Boiler

L_{AC} = Actual level of the Boiler

L_{RE} = Reference level of the boiler

HP = Head Pressure

Analog to Digital Convertor

It is the major part of control scheme, which converts convert analog into digital signals. The Analog to Digital Converter (ADC) 0809 has 8 channels of analog inputs. The ADC0809 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8-single-ended analog signals. The device eliminates the need for external zero and full-scale adjustments. Easy interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched TTL outputs. The design of the ADC0809 has been optimized by incorporating the most desirable aspects of several A/D conversion techniques. The ADC0809 offers high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability, and consumes minimal power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications.

Timer

The 555 Timer IC is an integrated circuit (chip) implementing a variety of timer and multi-vibrator applications. It has some functional blocks, that is shown in figure 16. The 555 has three operating modes

a) Monostable mode b) astable mode c) bistable mode

Digital to Analog Converter

The Digital to Analog Converter (DAC) 0832 is an advanced CMOS/Si-Cr 8-bit multiplying DAC designed to interface directly with the 8051/8052 and other popular microprocessors. A deposited silicon-chromium R-2R resistor ladder network divides the reference current and provides the circuit with excellent temperature tracking characteristics (0.05% of Full Scale Range maximum linearity error over temperature). The circuit uses CMOS current switches and control logic to achieve low power consumption and low output leakage current errors. Special circuitry provides TTL logic input voltage level compatibility. Double buffering allows these DACs to output a voltage corresponding to one digital word while holding the next digital word. This permits the simultaneous updating of any number of DACs. The DAC0830 series are the 8-bit members of a family of microprocessor-compatible DACs (MICRO-DAC).

Parallel port

Parallel Printer Port has a total of 12 digital outputs and 5 digital inputs accessed via 3 consecutive 8-bit ports in the processor's I/O space. 8 output pins accessed via the DATA Port. 5 input pins (one inverted) accessed via the STATUS Port. 4 output pins (three inverted) accessed via the CONTROL Port. The remaining 8 pins are grounded. The PC parallel port adapter is specifically designed to attach printers with a parallel port interface, but it can be used as a general input/output port for any device or application that matches its input/output capabilities. It has 12 TTL-buffer output points, which are latched and can be written and read under program control using the processor instructions. The adapter also has five steady-state input points that may be read using the processors in instruction.

In addition, one input can also be used to create a processor interrupt. This interrupt can be enabled and disabled under program control. Reset from the power-on circuit is also ORed with a program output point, allowing a device to receive a power-on reset when the processor in reset. The input/output signals are made available at the back of the adapter through a right-angled, PCB-mounted, 25-pin, D-type female connector. This connector protrudes through the rear panel of the system, where a cable may be attached. When this adapter is used to attach a printer, data or printer commands are loaded into an 8-bit, latched, output port, and the strobe line is activated, writing data to the printer. The program then may read the input ports for printer status indicating when the next character can be written, or it may use the interrupt line to indicate not busy to the software. These input ports are used for sending the data from the transducer to the system.

Optocoupler

One of the simples optoisolated output circuit for parallel port is the following 4N33 based circuit. The 4N33 optocoupler device has a Darlington output transistor that is capable of driving up to 30 mA of load safely. The maximum voltage on the output side is 30V. The input to output isolation can handle up to 1500V voltage. You connect the input side to the parallel port output pin you want to use for the controlling. Then you connect the input - side to parallel port ground pin. You can expect to get something like 10 mA of drive capacity on output (maybe more if you are lucky to have a coupler with high CTR and parallel port with high output current). The circuit can be built also using 4N32 optocoupler that is very similar to 4N33.

Relay Unit

The circuit can handle relays which take currents up to 100 mA and operate at 12V or less. The circuit need external power supply which has the output voltage which is right for controlling the relay (5..24V depending on relay). The transistor does the switching of current and the diode prevent spikes from the relay coil form damaging your computer (if you leave the diode out, then the transistor and your computer can be damaged). The circuit can be also used for controlling other small loads like powerful LEDS, lamps and small DC motors. Keep in mind that those devices you plan to control directly from the transistor must take less than 100 mA current.

Feed Water Control Valve

Pneumatic Actuator is Control to Feed Water Control Valve. The Valve Operating range is 5 to 25psi. It is a diaphragm type valve.

Result

Boiler Drum level is obtained in our project is based on reference value of set point and one of set point value given below. The drum level output wave is shown in the figures 2 and 3.

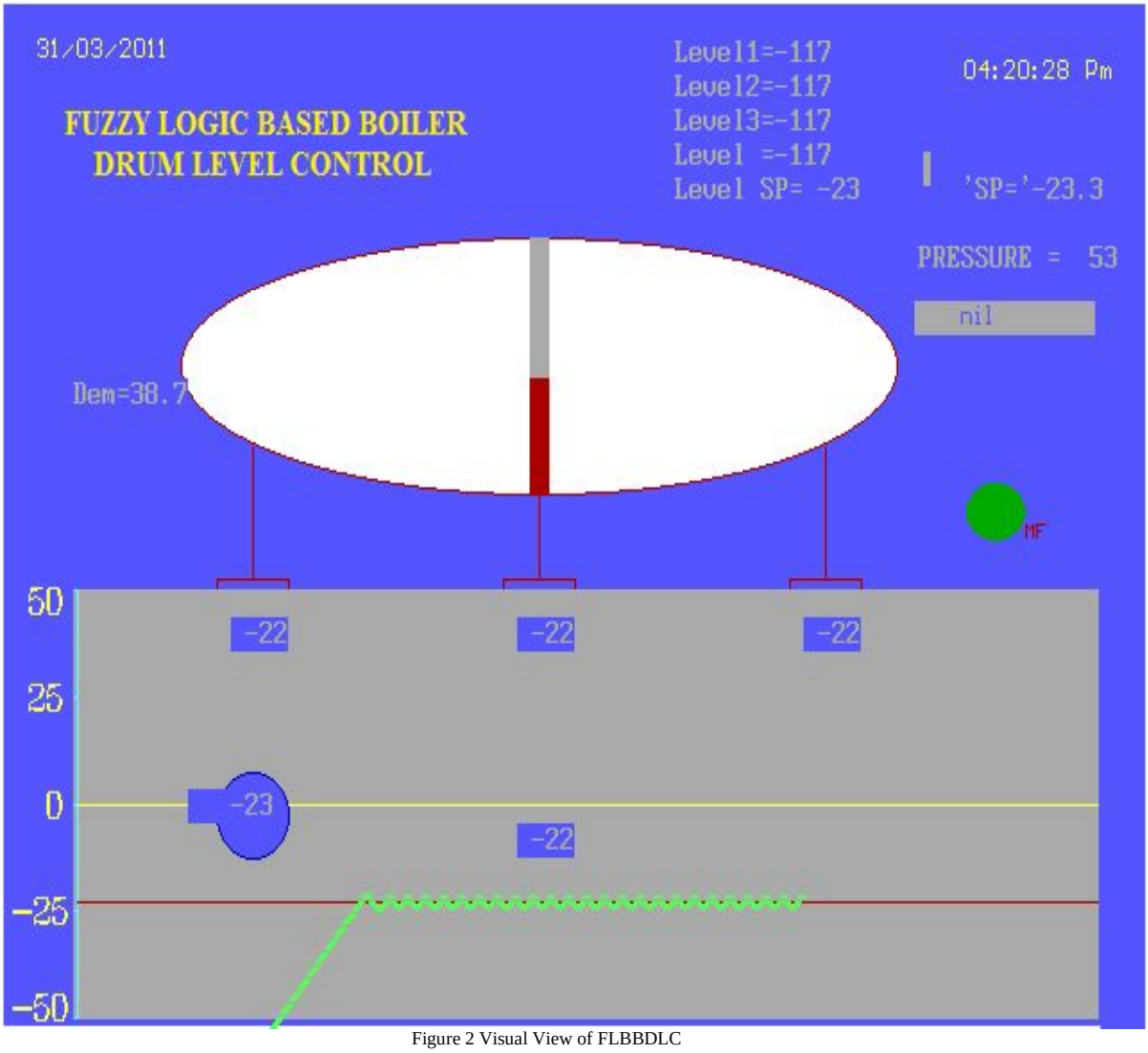
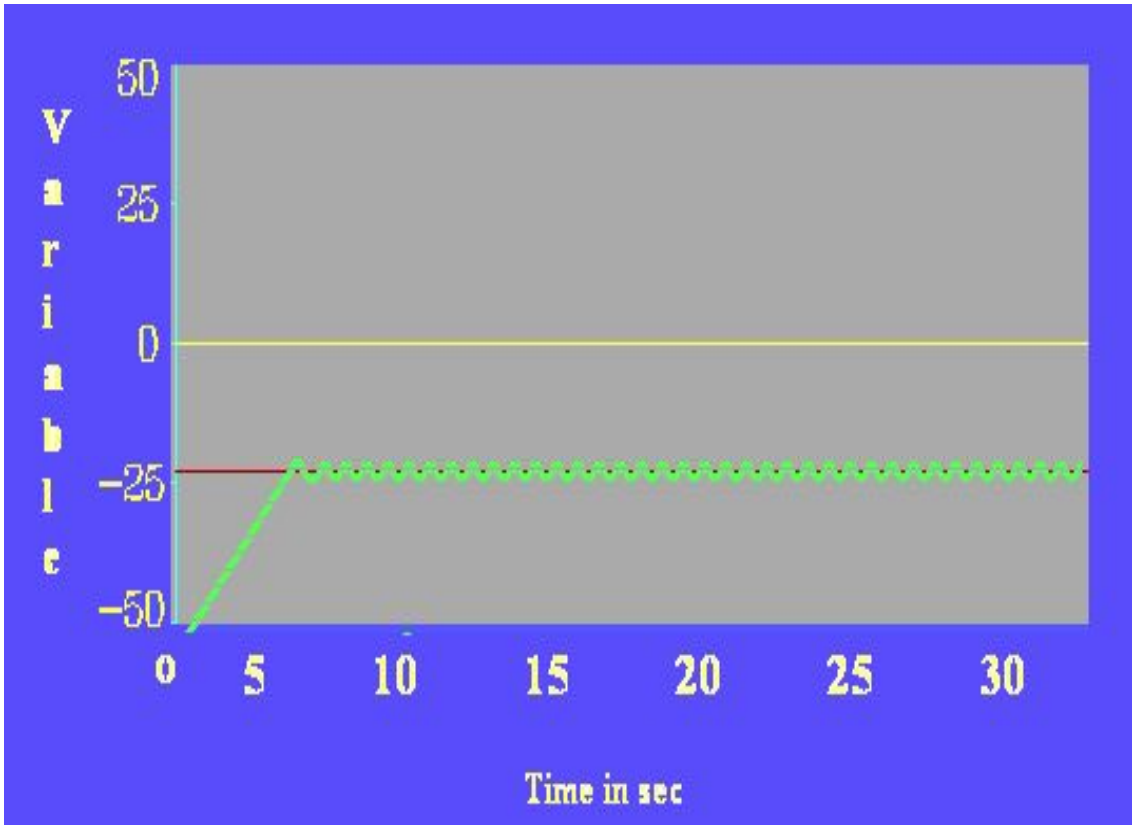


Figure 2 Visual View of FLBBDLC



SET POINT IS -20

Figure 3 Output Response of Drum Level

In this project the level is maintained by the set point and level is controlled without any oscillation or overshoot. The output expected from the fuzzy logic and controlled actual drum level to be much appreciable straight line when compared to present PID based control. It is expected more intelligent control even in emergency situation. In addition to drum level control, an additional fuzzy logic is implemented on drum level very high and very low situation arises. Fuzzy logic control provides better monitoring, control and protection. It performs fast actions in case of emergency and very critical conditions in the boiler. It is very sensitive with small variations and has perfect control all over the range.

IV. CONCLUSION

The fuzzy logic based Boiler Drum Water level control is simulated and experimented successfully using a prototype model and the results are also verified. So, we can conclude that the fuzzy logic based boiler feed water level control is working properly and the results obtained are very promising and satisfactory. 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 feed water control applications but it has some disadvantages and errors when there is variation of load and nonlinearity arises in the system. Intelligent control system like fuzzy control works efficiently under varying environments and can be easily implemented in industrial boiler feed water control applications as well as in other water level control applications. It can also be efficiently applied for boiler temperature-level control and similar applications.

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