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An Intelligent Approach in Monitoring and Controlling of Bunker Coal Level in Thermal Power Plant

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Abstract

Currently coal fired power plant requires bunker or stock piles in order to place the coal for storage purpose and to use it effectively when demand arises. Real time sensors are used to sense level of the coal and to pass data to computational systems for processing hence further actions such as refilling and distributing of coal can be automated. Further the control action in level sensing can be enhanced by using fuzzy logic controller which is an intelligent system. Thus the proposed system of coal unit provides the optimum control with increased efficiency. The simulation results are achieved by using LabVIEW.

Keywords: *Fuzzy Logic, LabVIEW and Membership function*

1. Introduction

Mostly coal is used as a main fuel in thermal power station. As the consumption of coal is huge, the layout of a coal handling plant should be simple, reliable and with low maintenance. Coal is brought to power station by two means of coal transportation *i.e.*, roadways, railways. Coal brought by railways is unloaded with the help of wagon tippler in a coal hopper. The movements of wagons are controlled by automatic in-haul and out-haul battle chargers. This coal is then fed on coal conveyor belt through vibrating feeder. These feeders are of electro-magnetic type and controls the rate of feeding required for bunkering. By the various combinations of conveyor belts, coal is conveyed to the surge hopper of a crusher house. Before the coal comes to the crusher house, the ferrous materials like stones, shells, wood etc. are removed manually.

From surge hopper, coal is fed to the coal crusher through mechanical feeder [1]. Here coal is crushed to the size of 20-25 mm. This coal is then sent to coal bunkers through various belts and finally to coal trippers and here it is stored for further processing which may be combustion in boiler furnace. This cycle is known as bunkering cycle. If bunkers are full or coal is not required due to any reason on units, then coal is diverted to the stack yard with the help of stacking conveyor belts. This cycle is known as stacking cycle. If coal is not available from any means of coal transportation and coal is urgently required for the unit, then the stacked coal is diverted to the bunkers with the help of reclaiming belts. This cycle is known as reclaiming cycle. Nowadays, this stacking and reclaiming of coal is done with help of an automatic stacker cum reclaims.

Boiler is a device for generation of steam for power generation. In thermal power stations water tube boilers are used. Boiler is suspended from the top on four columns and

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kept free from the bottom side for free expansion on downward direction. Hard coal and brown coal are the main energy carriers in coal-fired power plants. Delivered by train, the coal is unloaded into bunkers up to 30 m high. The coal then goes through a moderate grinding process and then is stored in the coal bunker. Afterwards the coal is typically delivered to a power plant via rail or conveyor belt. The coal is transported by conveyor and tripper cars to coal hoppers. The ongoing deregulation of the power generation industry is making plant efficiency a top concern.

For fossil fired stations, the inventorying and blending of coal (which represents the single largest cost component) is essential. Fundamental to this is proper coal handling, both at the coal yard, and more importantly, in day use bunkers [2]. Complete automation schemes include Continuous tripper car positioning, Continuous bunker level monitoring, Bunker volume profiling. A combination of the above three elements forms the corner stone of proper coal handling methodology. Tripper car location can be completely automated, and operated on pre-programmed cycles. Complete bunker level includes the ability to measure down to the pulverizes circuits past the smallest discharge chute on the largest bunker. In this manner, bunkers can be completely burned down, and accurate level information can be obtained when layering to ensure the tonnage loaded corresponds to the demand period when the blend is to be fired.

2. Literature Survey

[1] Pruessmann, D. *et al.* (July 1997) Published a Paper on "Fuzzy logic supervisory control for coal power plant"- A new type of fossil fuel power plant was developed by two German companies, Rheinbraun and RWE. This new type of fossil fuel power plant uses brown coal. The brown coal is first gasified and then the gas is used to run a combined gas turbine/steam turbine process. Rheinbraun developed the process that is used to gasify the brown coal. It has been used and optimized since 1985 in a large-scale demonstration plant. This demo plant is equipped with a conventional control system. But to be able to build the new type of power plant the following improvements are necessary: more exact control of gas throughput; increased degree of automation; and automatic adaptation of the control to different coal qualities. A supervisory fuzzy logic control was added to the control system to achieve these improvements. Fuzzy logic technology was used because of the nonlinear MIMO characteristics of the process. Fuzzy logic also makes it very easy to convert the extensive operator knowledge into a clearly defined control strategy.

[2] Betin, F *et al.* (June 2000) Published a Paper on "Fuzzy logic applied to speed control of a stepping motor drive"- Nowadays, thanks to the development of microprocessors, stepping motors are widely used in robotics and in the numerical control of machine tools where they have to perform high-precision positioning operations. Nevertheless, the variations of the mechanical configuration of the drive, which are common to these two applications, can lead to a loss of synchronism for high stepping rates. Moreover, the classical open-loop speed control is weak and a closed-loop control becomes necessary. In this paper, the fuzzy logic principle is applied to control the speed of a stepping motor drive with feedback. An advanced test bed is used in order to evaluate the tracking properties and the robustness capacities of the fuzzy logic controller when variations of the mechanical configuration occur. The experiment has been performed using a low-cost 16 bit microcontroller in order to verify the design performance

[3] B. De Baets, D. Dubois, E. Hullermeier *et al.* (August 1978) Published a Paper on "Fuzzy Sets and Systems"-The theory of fuzzy sets now encompasses a well-organized corpus of basic notions including (and not restricted to) aggregation operations, a generalized theory of relations, specific measures of information content, a calculus of fuzzy numbers. Fuzzy sets are also the cornerstone of a non-additive uncertainty theory, namely possibility theory, and of a versatile tool for both linguistic and numerical

modeling: fuzzy rule-based systems. Numerous works now combine fuzzy concepts with other scientific disciplines as well as modern technologies. In mathematics fuzzy sets have triggered new research topics in connection with category theory, topology, algebra, analysis. Fuzzy sets are also part of a recent trend in the study of generalized measures and integrals, and are combined with statistical methods. Furthermore, fuzzy sets have strong logical underpinnings in the tradition of many-valued logics.

[4] Robert N. Lea *et al.* (May 1989) Published a Paper on "Applications of fuzzy sets to rule-based expert system development"- In this paper, problems of implementing rule-based expert systems using fuzzy sets are considered. A fuzzy logic software development shell is used that allows inclusion of both crisp and fuzzy rules in decision making and process control problems. Results are given that compare this type of expert system to a human expert in some specific applications. Advantages and disadvantages of such systems are discussed. In thermal power plant there are totally two units. In each unit there are totally four coal bunkers. The sized coal is passed through screen house and crusher house to reach belt conveyor and then it finally reaches the bunker units. This cycle is known as bunkering cycle. If coal is over fill in the bunkering unit, we need to stop the coal filling process. So shut down the belt conveyors, screen house and crusher house.

3. Existing System

In the existing system to shut down the process the PID controller is used. PID controller takes bunker level as the input parameter and control action to the conveyor belts as the output parameter. The input is sensed by the ultrasonic sensor and it is communicated with the help of cables. The output was send to the DC motor to stop or start the conveyor. These are the basic parameters and operations of existing system. When PID controller alone is used it can give poor performance while PID loop gain is reducing, so that the control system does not overshoot, oscillate or hunt about the control set point value. They also have difficulties in the presence of non-linearity's, and regulation versus response time, it do not react to changing process behavior (say, the process changes after it has warmed up), and have lag in responding to large disturbances.

4. Proposed System

This project overcomes the drawbacks of the PID controller with the replacement of FUZZY controller. With the use of fuzzy controller in the process the control action can be increased at many parameters. The bunker level and coal weight at the belt conveyor 1 is the input parameters similarly screen house, crusher house, belt conveyor 1 and belt conveyor 2 are the output parameters of the proposed system. It will increase the control action accuracy of the bunker level. The goal of this work is to study the performances of a fuzzy controller and to compare it with a classical control approach.

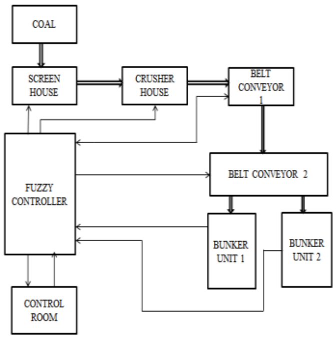

Figure 1. Block Diagram of Proposed System

Load cells are placed in the belt conveyor 1 to measure the carrying coal weight in kg/ms. Ultrasonic sensors are placed in top of the bunker units, sensor transmit the coal level in meters. At the output side, the first output controls the speed of the belt conveyor 1. The next output is change of direction (reverse/forward) of the belt conveyor 2. The other two outputs trip the crusher house and screen house. Input and output variables are interface with the fuzzy controller. The coal handling process depends on the inputs and output variables for which the FUZZY RULES are created in the fuzzy rule base. The block diagram of the proposed system is shown in Figure 1.

4.1 Fuzzy Logic Controller

Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensor or other inputs, such as switches, thumbwheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value.

4.2 Linguistic Variables

While variables in mathematics usually take numerical values, in fuzzy logic applications, the non-numeric linguistic variables are often used to facilitate the expression of rules and facts.A linguistic variable such as age may have a value such as young or its antonym old. However, the great utility of linguistic variables is that they can be modified via linguistic hedges applied to primary terms. The linguistic hedges can be associated with certain functions.

4.3 Max Membership Principle:

It is also known as the height method

$$\mu_c(z^*) \geq \mu_c(\text{z}) \qquad \text{for all z} \in Z$$

Figure 2 and 3 shown the assignment of input and output variables and allocating membership function for those variables.

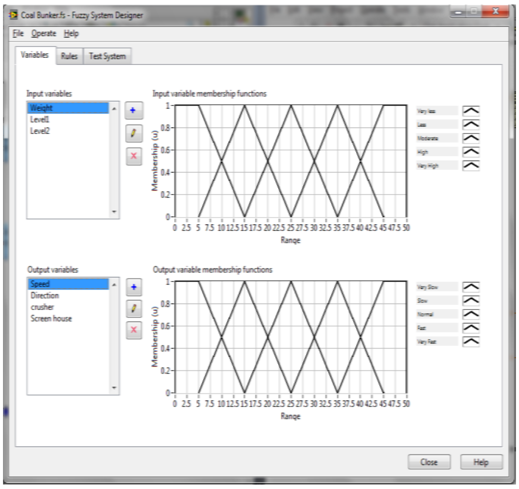

Figure 2. Assigning Input and Output Variables

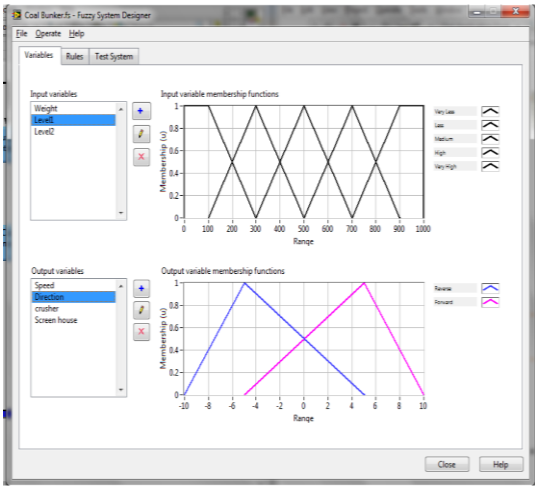

Figure 3. Assigning Membership Function for Variables

5. Software Simulation

5.1 LabVIEW

LabVIEW is a highly productive environment that engineers and scientists use for graphical programming and unprecedented hardware integration to rapidly design and deploy measurement and control systems. Within this flexible platform, engineers scale from design to test and from small to large systems while reusing IP and refining their process to achieve maximum performance. LabVIEW software is ideal for any measurement or control system, and the heart of the NI design platform. Integrating all the tools that engineers and scientists need to build a wide range of applications in dramatically less time, LabVIEW is a development environment for problem solving, accelerated productivity, and continual innovation.

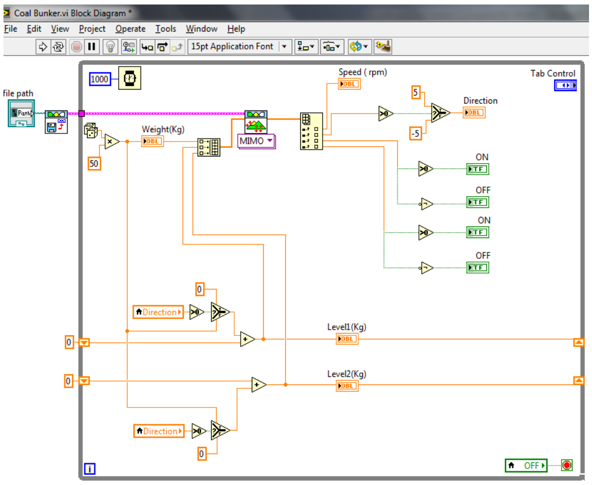

Figure 4. Block Diagram of the Process in LabVIEW

The block diagram of the proposed system in LabVIEW is shown in Figure 4. For the weight to be sensed periodically for each second the process is executed in while loop which runs for every 1000 millisecond. The file path control is used to access any file from a desired location. In this case the location where the fuzzy controller is saved is mentioned in the front panel. The fuzzy controller is loaded into the load fuzzy system component next to it. This loaded fuzzy system is loaded into the fuzzy controller. The fuzzy controller is an MIMO controller which has three inputs and four outputs in this case.

Weight and bunker levels are inputs while speed, direction, crusher and screen house are outputs. To produce an assumptive changing weight the random number function is used which generates a random number between 0 and 1 for every loop. This random number is multiplied with 50 so that a varying value between 0 to 50 kg passes in the conveyer each second. Levels are inputs to fuzzy controller but their inputs are from the weight passing through conveyer. At a single instant, only one of the bunkers gets filled. Based on the direction of the conveyer the coal fills in either bunker 1 or bunker 2. Weight is added to either one of the bunkers after checking the direction of the conveyer. Direction in turn depends on the level of coal in the bunkers.

If coal is very high in bunker2 and bunker1 has less coal then conveyer gets reversed. Also if there is any clot in the outflow of coal from bunker to furnace the level increases to its higher limit. If level of both bunkers exceeds higher limits then the crusher and screen house go OFF. Once the crusher and screen house shut down the process automatically shuts down. Shift registers are used to sum up the level of the bunkers in the while loop. The build array function is used to append an array for given input elements with which input is given to the fuzzy MIMO controller. The output values are obtained using an index array which returns the element of the array. The shift registers are initially set to zero so that when the process starts the levels of the bunkers start from initial state.

6. Simulation Results

6.1 VI for Coal Bunker

The VI of the coal bunker is a single VI and a fuzzy control design without any sub VIs. The first step in the simulation is to create a fuzzy controller. The fuzzy controller is designed using fuzzy control designer.

6.2 Front Panel

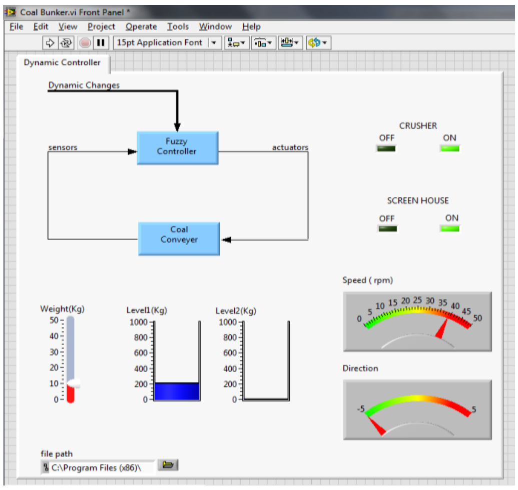

Figure 5. Process at its Initial Stage

The Figure 5 has shown the process taking place at its initial stage. The LEDs indicate the ON state and OFF state of the crusher and the screen house and their corresponding conveyers. If a situation occurs where the coal from the bunkers don't move into the furnace due to a clot. In such case the coal conveyance has to be stopped until the problem is cleared. Also the crushing and screening has to be stopped to prevent power wastage.

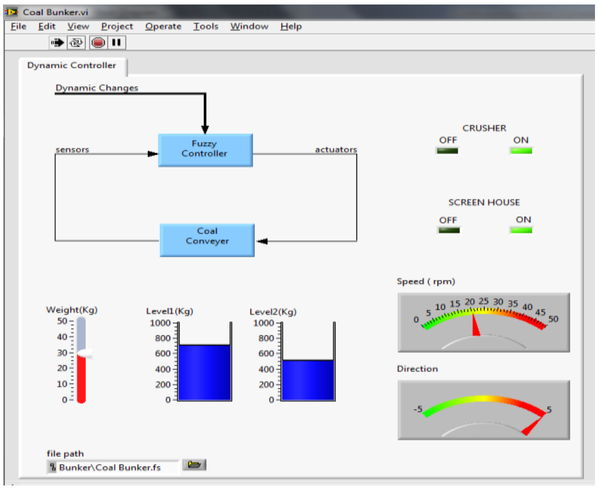

Figure 6. Process when Conveyor Direction Gets Reversed

The Figure 6 shows the process when conveyor gets reversed. As the process starts, the speed of the conveyer varies in inverse proportion to the weight of coal measured in the conveyer. The coal fills in bunker1 as the conveyer is in reverse direction. After a certain time the level of bunker1 goes very high and level of bunker 2 still is at initial state. Now the conveyer gets forwarded and the bunker 2 gets filled with coal. This process goes on without any change in the direction until buker2 also gets filled considerably. In this case the crusher and screen house still remain working because the coal has not exceeded the maximum heights of the bunkers. The level of coal filling in the bunker 2 gradually increases to the same level to which bunker1 was filled previously.

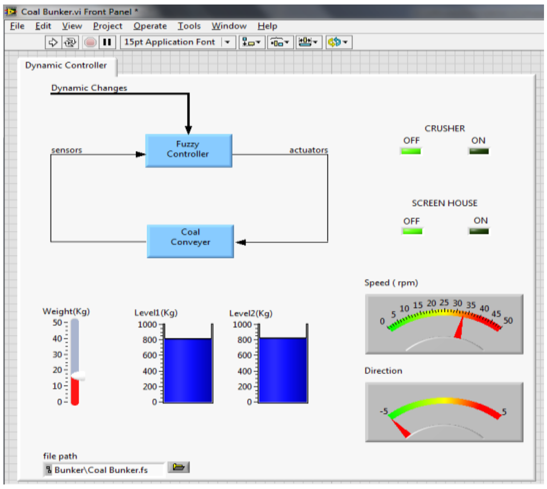

Figure 7. Process when Crusher and Screen House Shutdown

The Figure 7 shows the process when crusher and screen house got shutdown. When this condition occurs, the conveyer again reverses and the level of bunker1 increases. The two bunkers now get filled simultaneously until they reach the maximum limit. When the maximum limit is reached the crusher and screen house go off and the whole process is shutdown

7. Conclusion

The fuzzy control algorithm is a newly developed algorithm which is easy to use and adapt to any system of use. FLC provides an efficient method of control with a very low time lag and a high speed of response. Since this control is newer one and it implements rules in native language itself hence designing of such control action becomes easy. The control system becomes more user-friendly while using fuzzy. Conventional controllers have a serious disadvantage of hectic mathematical modeling which involves simplification of complex differential equations and fuzzy system eliminates all of those. Thus by having an intelligent system in monitoring and control of bunker coal level, the entire process can be optimized with high speed which may leads to increased efficiency.

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