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INDUSTRIAL POLLUTION CONTROL USING INTELLIGENT CONTROLLERS

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ABSTRACT

Environmental pollution due to process industries is one of the major area to be taken care of in the growing industrialization. In this paper it is described to control the pollution at the instant of formation of pollution, which has been achieved by the use of intelligent controllers. This control strategy has been implemented in a 2500 tons per day (tpd) dry cement plant.

INTRODUCTION

The environmental pollution is the undesirable side effect of increasing inustrialization and the congregation of industries near the area, which is already heavily industrialized and the unchecked population growth. At present, the rate of discharge of pollutants into the atmosphere exceeds the rate of cleaning of atmosphere, thereby progressively degrading the natural ecosystem. The total environmental pollution due to the presence of industries is just one tenth of that of the pollution created by motor vehicles. The government and environmentalists give more importance to industries as it is easy to control hundreds of industries rather than to control thousands of motor vehicles, and also industries do not have any financial and technology constraint. The pollution created by process industries is due to the incomplete combustion of fuels which result in the harmful gases, such as carbon monoxide (CO), unburnt hydrocarbons (HC), various oxides of nitrogen (NO_x) and sulphur, aldehydes, lead compounds, and particulate matters in smoke. Carbon dioxide (CO_2), sulphur dioxide (SO_2) and NO_x gases emitted produce carbonic, sulphuric and nitric acids, respectively as they react with the atmospheric water vapour, giving rise to so called ACID RAIN with low pH values. This affects severely the aquatic and terrestrial ecosystems. Oxides of sulphur and nitrogen are the major contributors to acid rain. Nearly 30 per cent of acidity of rain water is due to various oxides of nitrogen (Sharma, 1986). Also all the oxides of nitrogen except N_2O are highly poisonous.

The dust particles in the smoke can easily be controlled to a minimum level by using electrostatic precipitators (ESPs) and other filters, and SO_2 and NO_x can be reduced to a certain level by proper desulpherization and denitrification of fuels. During dust control if the carbon monoxide (CO) content in the exit gas exceeds a certain limit then there will be explosion inside the ESPs, so this is also to be taken care of. In most of the process industries the formation of oxides is inherent during the chemical reaction phase, which can not be sacrificed as it will affect the end product. Cement process is an example of such a case. In these cases, to limit the formation of oxides up to a desirable extent, can only be achieved by controlled reactions of the materials, that is, to minimise the formation of oxides at very instant of creation, in such a way that the end product quality will not be hampered. It is not so easy, because in all the process industries for the particular product these reactions are to be there and so also the oxide formation. In cement plant where during the chemical reaction phase both carbon monoxide (CO) and nitrogen oxides (NO_x) are created. In this paper we have discussed how real time fuzzy logic controller helps in reducing the pollutions created by the cement plants. This work has been developed and tested in a 2500 tpd capacity cement kiln located at Jayanthipuram, Andhra Pradesh. The entire package is developed in Ramco Electronics Division, Madras. The impact of implementation of this controller on environment pollution control is well proved there.

REAL TIME FUZZY LOGIC CONTROLLER BASICS

Real time control has become a necessity for all process industries. The challenge before all control theorists to extend their concepts towards more advanced control theory and control technology in terms of system conceptualizing, modelling and identification in the domain for qualitative and symbolic computation. For time varying nonlinear, infrequently sampled processes in industries conventional control does not give a good answer. Here, experienced operators control from their own "rule of thumb". We will take one example.

Ram is "YOUNGER" than Shyam

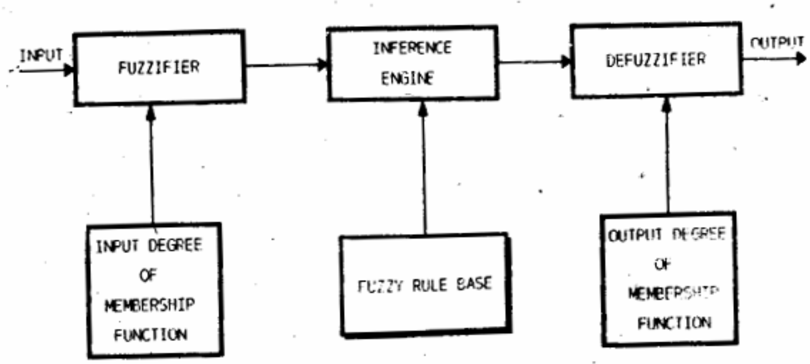

Fig. 1. Block schematic of Fuzzy logic principle

Here "YOUNGER" is not a well defined term rather a vague representation of age. These type of cases one will encounter frequently in real world. Fuzzy logic a technique (Zadeh, Sangalli, Van Hoof and Holmblad) developed by Zadeh in 1965, deals with these type of real world problems.

The Basic structure of rule based fuzzy logic system is shown in Fig. 1. It is essentially consists of a fuzzifier, inference engine and defuzzifier. Fuzzifier transforms the crisp process values (inputs) to a degree of membership function. The inference engine performs the rule matching as in the general expert system. The general format for rules is

IF < Condition> THEN < Action>

The defuzzification process transforms the fuzzy values to real crisp values based on output degree of membership functions.

POLLUTION IN CEMENT PLANT

Cement Process

Cement is manufactured by fine grinding the clinker which is produced in the cement kiln by heating a powdered mixture of different raw materials such as lime stone, clay and sand components. The raw materials are grained in a grinder and then blended for homogenization an fed to the kiln via storage silo, preheater and precalciner. Finally gypsum is added for proper strength. The entire process of cement manufacturing is shown is Fig. 2.

Pollution

The major threat of cement production towards environmental pollution is the release of carbon monoxide (CO) and nitrogen oxides (NO_x) and the dust particles in the exit gas. Dust particles are controlled using Electrostatic precipitators (ESPs) and cotton filters. The electrostatic precipitators will operate for certain temperature and carbon monoxide range. Electrostatic precipitators of different temperature ratings are available, but carbon monoxide (CO) gas creates a lot of problem which simply can not be avoided, the only solution for this problem is to keep as low percentage of carbon monoxide as possible in the gas passing through the ESPs. For economic reason low temperature rated ESPs should be used with effectively lowering exit gas temperature by utilizing the exit gas heat for different preheating operations in the cement process.

Nitric oxides are highly poisonous gases, will be evolved when the cement raw material mix will be heated up at high temperatures between 1400 to 1500 degree

Fig. 2. Cement processing steps

centigrade. The Carbon monoxide is formed when coal will not burn completely. Precalciner helps a lot in reducing the amount of carbon monoxide (CO) and nitrogen oxides (NO_x). The nitric oxides are formed in a rotary kiln at highest temperatures in the flame, at considerable expense of oxygen. A lightly reducing atmosphere which occurs zonally in pracalciners can result (in the presence or are material catalyst) in reduction of nitrogen oxides contained in the kiln gases. But reducing condition, i.e., inadequate oxygen in the kiln gas, during cement clinker burning substantially affect the colour of the clinker by producing ferrous oxides, accelerate the setting by enhancing tricalcium aluminate content at the expense of tetracalcium aluminoferrite ($4CaOAl_2\ O_3\ Fe_2\ O_3$), and reduce the strength by breaking down tricalcium sulphate during clinker cooling. So, for better clinker quality oxidizing conditions should be maintained.

Quality of the clinker depends on the free lime (CaO) content in the clinker. The lesser the free lime content better the quality of the clinker. Free lime content will be less if more and more free lime will bind during clinker formation. Usually at high temperatures more free lime starts combining with one part of the dicalcium silicate ($2CaoSiO_2$) and thus be converted to tricalcium silicate ($3CaoSiO_2$). So, more the burnig zone temperature the less the fee lime in the clinker and better the quality.

Hence to get better quality at higher temperatures we have to sacrifice the fuel requirements and also high temperature results in a great stress on the kiln and the refractory lining, reduction in cement strength, formation of NOx etc. So, one has to optimimally control to get the best solution.

An optimized solution can be possible with optimized values for above parameters. This can be achieved by some kind automation of the plant with advanced controllers. Usually, cement plants are controlled by expert operators by a "rule of thumb", a vague resoning. No mathematical model is possible for this plant as it is a very complex nonlinear multivariable process. Fuzzy logic is the technique which does not depend on any model and is proved to be the best for this problem, which deals with all kinds of uncertainties.

FUZZY LOGIC BASED CONTROLLER

The basic input output details of the controller is shown in Fig. 3. This controller is basically designed for a 2500 tpd rotary cement kiln employing dry process. this controller, of course, can be used for any cement kiln control with modification of the rule sets and the input output membership functions. The input parameters are available from the respective transducers in terms of a voltages. all the inputs were normalized to a unit scale. The final normalized output is then scaled to the required range.

This controller rule block consists of expert rules derived from experts. This keeps track of the process all the time and takes action immediately so that a constant specified action for the particular problem taken place without any intervening error those are common in human operators.

The temperature of the burnig zone inside the kiln which plays very important role as discussed above is not directly measurable. To get one approximate

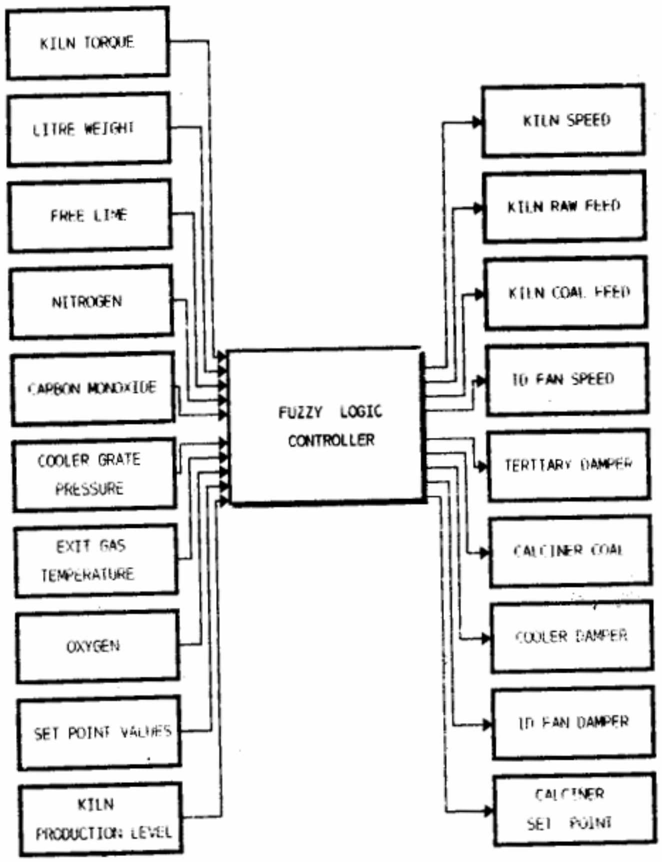

Fig. 3. Input output description of the fuzzy controller

temperature, here a new statistical predication method has used. Which given almost correct answer and depends on the value of free lime and the litre weight of the clinker.

RESULTS

This fuzzy logic controller has been developed using C programming language in a 80386 based system under DOS. This has been tested in a 2500 tpd capacity cement plant situated at jayanthipuram, Andhra Pradesh. During the commissioning period it has observed that the exit gas is satisfying all the regulations and limitations set up by Pollution control Board, Government of India.

CONCLUSION

This paper described the role of a fuzzy logic controller as an intelligent controller for pollution control. This controller helps in judging the actual situation so as to operate the process within the set constraints, which in turn gives the best output. Increased number of industries implies combustion of more fossil fuel which means emission of more CO_2, SO_2, NO_x and CO, thereby enhancing acid rain formation and related hazards. this growing threat on living and non-living system should be taken seriously to save our planet. Hence all the process industries should look forward to use intelligent controllers to make the environment clean, in addition to more yield and better quality of product.

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