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System Identification and Comparison of Ziegler-Nichols and Genetic Algorithm for Moisture Process

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Abstract: Moisture maintenance at a particular phase is of primary importance in various industrialized applications such as food processing and pharmaceutical industries. In this effort a laboratory level humidifying arrangement is experimentally tested. A step input was introduced into the arrangement and consequential comeback is analysed. From the comeback, the replica was recognized and validated with premeditated records. For the replica, diverse control strategies such as Ziegler Nichols based Proportional Integral Controller (ZNPID) and Genetic Algorithm (GA) was tested in MATLAB environment. The performance of the controllers based on time sequence stipulations like rise time, settling time and overshoot were studied.

Keywords: Moisture, ZN-PID, GA.

I. INTRODUCTION

Humid air plays a vital role in day to day life activities. Moisture is the mixture of water content and other constituents of air. It is represented in terms of Relative Moisture (RH), which is the ratio of amount of water vapour content in air to the maximum amount of water the air can absorb, expressed as percentage (%) when air cannot absorb any more moisture; its relative moisture is 100%. The role moisture plays a very important role in industrial sector and also to the human comfort. The RH level has, to be maintained in many Industries like pharmaceuticals, textiles, sugar, tobacco, silicon wafer deposition industries to get a desired output of the product [1]. It is very essential for the researcher and industrial unit to study the effect of RH. Liau and Huang conducted a study experiment on photonic band gap film in silicon formation and concluded that the quantity of crystal and stop band intensity was more efficient under controlled RH [2]. Enhsen studied that the energy consumption was affected heavily by air moisture due to annual heating and cooling [3]. Many control technique for moisture is available in literature. The control methodology for moisture and temperature control was proposed by Guo, Cao and Zheng [4] in intelligent industrial workshop. Ziegler and Nichols [5] developed a conventional and traditional tuning strategy. It was performed by setting the integral and derivative gains of the process to zero. The proportional gain is increased from zero till it reaches the ultimate gain. The output of the control loop oscillates with constant amplitude. The oscillation period is used to set the P, I, and D gains depending on the type of controller used. Z-N method suggested that the ultimate gain and ultimate period are determined by the closed loop test of the process model [6]. The main objective of this paper is to determine the model for a humidifying process, and to develop different controllers for this process, comparing the results of ZN-PID and GA.

II. EXPERIMENTAL SETUP

Fig. 1 shows the outline design of the moisture method. The air compressor is worn to deliver air of preferred pressure. The compressed air is passed into the moisture chamber via rotameter. The rotameter is a tool that measures the compressed air flow rate coming out from air compressor. The compressed air flow rate that is introduced into the moisture chamber is manipulated using the hand valve. The moisture chamber is a blocked container. The chamber is packed with water of preferred level. The moisture chamber is having the dimensions of 140mm length, 100mm breadth and 175mm height. Pressurized air is conceded through the chamber, it forms air bubbles. As a consequence of this, humidified air is attained which is ready to pass through the helical coil. The coil produces time lag for this progression. Honeywell make sensor HIH – 3610 is worn to compute the exit air relative moisture (RH) from the helical coil [7]. A step magnitude of 0.1 liters per

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minute (LPM) in air flow rate is abridged into the moisture chamber. The exit air RH from the delay coil is calculated and recorded with reverence to time.

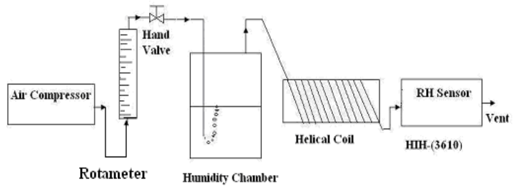

Fig. 1 Block diagram of the experimental setup

III. SYSTEM IDENTIFICATION

All The replica parameters were attained as recommended by Sundaresan and Krishnaswamy[8]. They anticipated a scheme where two points were elected from the graph subsequent to the time taken for the response to reach 35.3% and 85.3% of the eventual value that is t_1 and t_2 correspondingly. The subsequent equations are worn to guesstimate the time delay (θ) and time constant (τ) [9].

$$\theta = 1.3t_1 - 0.29t_2$$

$$\tau = 0.67(t_1 - t_2)$$

The gain K is established by means of the ratio of change in output to change in input. The replica obtained is given as

$$G(S) = \frac{184.64e^{-0.75s}}{5035S+1} \quad (1)$$

The attained replica was validated with the investigational records as shown in fig. 2 which shows minimum error between investigational and theoretical model. Based on the association of various data, the values of ϴ and τ more or less diminish the divergence among calculated comeback and the replica. It is a step retort based scheme which avoids the exploit of point of inflection on the process step response to approximate the time delay [10].

IV. CONTROLLER DESIGN

The replica attained flawlessly describes the plant. The attained replica was worn to replicate diverse control schemes since it is obligatory to sustain the RH to a explicit value to accomplish the product excellence.

A. ZN based PID Controller (ZNPID):

Several methods have been recommended in literature for designing a controller of a plant. A Z-N tuning rule is a closed-loop tuning technique proposed by Ziegler-Nichols (1942) which is still worn at present in one form or another. The Z-N rules are measured merely as estimated settings for adequate control [6]. The customary Z-N tuning rule serves as the foundation for an forthcoming generation in PID technology. With Z-N tuning rules, engineers had a methodical and realistic way of tuning PID loops for enhanced concert. The Z-N rule serves as an aid for learning PID tuning rule which produces fine values for the three PID controller gain parameters.

1. K_c –gain.
2. τ_I –integral time constant.
3. τ_D –derivative time constant.

Using the values of ultimate period P_u and ultimate gain K_u, Ziegler and Nichols prescribed the values K_c , τ_I and τ_D depending on the sort of controller used.

$K_u = \frac{1}{A}$ - ultimate gain.

$P_u = \frac{2\pi}{\omega_{co}} = \frac{radians\ /cycle}{radians\ /sec} = \frac{sec}{cycle}$ - ultimate period.

Zeigler and Nichols projected two methods namely step response and frequency method. Investigating step response scheme and in- depth gives profound perceptive understanding to new tuning rules [11]. Analysis of Z-N frequency response for tuning PI controllers have severe restrictions which could be trounced by a uncomplicated amendment for the progression where the time delay is expected [12]. The flaws of Z-N ultimate gain method are minute stability margin and it is a assessment and fault practice [13].

TABLE I
ZN-PID CONTROLLER

Type of Controller	$G_c(s)$	K_p	K_i	K_d
Proportional +Integral+Derivative(PID)	$K_c(1 + \frac{1}{\tau_1 s} + \tau_d)$	$0.60K_c$	$\frac{2K_p}{T_u}$	$\frac{K_p T_u}{8}$

B. Genetic Algorithm:

Genetic Algorithm (GA) is an optimization based intellectual system, which was established by Holland in 1970. GA is used to work out tricky tribulations rapidly and reliably. These algorithms are trouble-free to interface with existing simulations and models, and they are easy to hybridize. GA has three chief operations they are Selection, Crossover and Mutation, in addition to it has four control parameters: population size, selection pressure and crossover and mutation rate [14].

Selection is made arbitrarily by selecting the chromosomes from the existing generation population which is to be integrated in the population of the next generation. In brief, the GA starts with a community of chromosomes known as the initial population. Taking into account time and computer power factors, population size is heuristically selected not more than 100 chromosomes. Then, the chromosomes of parameters are passed to the objective function and fitness function for evaluation. Among the chromosomes in the population, some of them will be arbitrarily selected [15]. This selection component in the GA guides the algorithm to the solution by preferring individuals with high fitness over low-fitness. In other words, the chromosome with higher fitness function value will have higher chances of being selected. Crossover is the process of

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creating one or more offspring from the parents. The crossover allows the parents to exchange their information by swapping the genes between the chromosomes. Simple one point crossover method is used in this work. The last component of the GA is mutation. Mutation can be defined as the random deformation of the chromosome by randomly changing its bit string value. This process is performed to avoid the algorithm from stuck at local minimum by introducing traits not in the original population [16].

Implementation of GA

The values of K_p and K_i was found using GA. Controller Parameter are adjusted so as to minimize the error criterion, the objective function are also minimized [17]. It is determined that the controller settings are estimated and results are stable in a closed loop response.

Initialization of Parameters

To start up with GA, certain parameters need to be defined. It includes the population size, bit length of chromosome, number of iterations, selection, crossover and mutation types [18] etc. Selection of these parameters decides to a great extent the ability of designed controller. The range of the tuning parameters is considered in the range of 0-10. Initializing the values of the parameters for this paper is as follows:

Population size – 100
Bit length of the considered chromosome – 6
Number of Generations – 100
Selection method – 'Maximum Geometric selection'
Crossover type – 'Single point crossover'
Crossover probability – 0.8
Mutation type –'Uniform mutation'
Mutation probability – 0.05

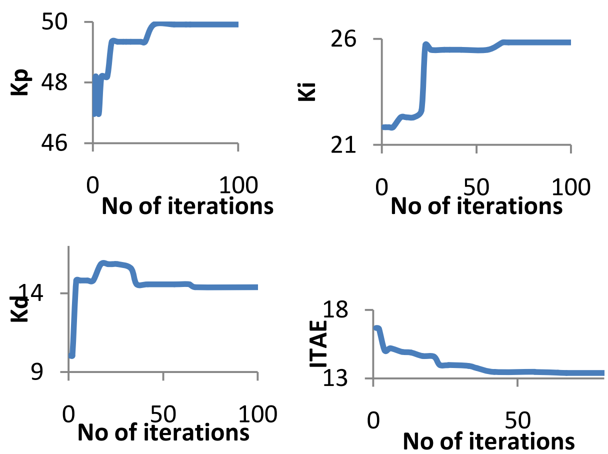


Fig. 2 GA Iterations

V. SIMULATION RESULT

The replica was recognized for the moisture course of action using SK technique which ended with minimum error involving the plant and the model. Since it is enviable for the industries like textile, food processing and pharmaceutics, diverse control techniques were intended and tested for this progression and compared for time domain specification. The normalized RH was in use for unit step response for the sake of simplicity. Fig. shows the comparison of diverse control schemes for the moisture process.

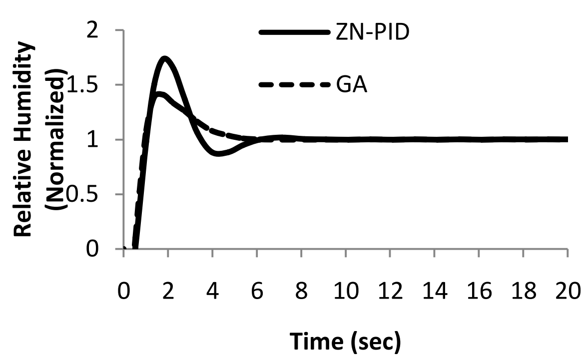


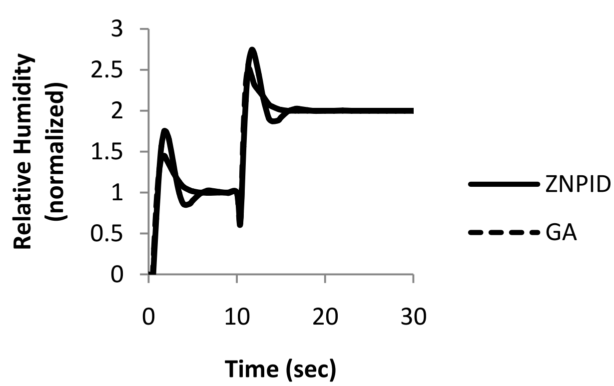
Fig. 3 Normalized values of ZN-PID and GA

TABLE III
TIME DOMAIN SPECIFICATION

Time Domain Stipulations	ZN-PID	GA
Rise Time (sec)	0.9815	0.970
Overshoot (%)	73.6%	39.1%
Settling Time (sec)	10.55	8

TABLE IIIII
PERFORMANCE INDICES

Performance Indices	ZN-PID	GA
IAE	20.3556	13.8559
ITAE	37.0545	13.4245
ISE	14.7596	12.5076



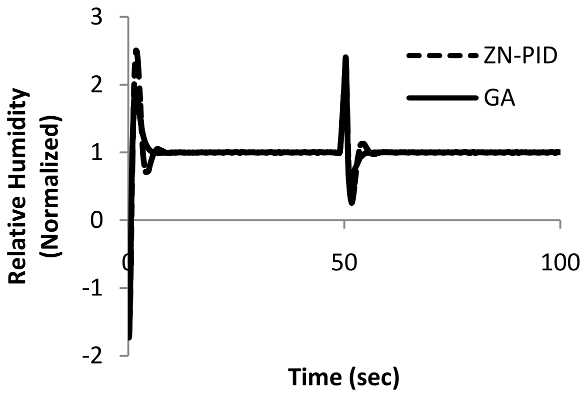


Fig.4 Servo and Regulatory Tracking.

TABLE IV
ROBUST SPECIFICATION

+20%	Specification	ZN-PID	GA
	IAE	19.1321	13.5043
	ISE	14.8245	13.1048
	ITAE	30.9233	12.4867
	MSE	0.0493	0.0435
-20%	IAE	21.8940	14.4479
	ISE	14.8652	12.0732
	ITAE	45.4957	15.5207
	MSE	0.0494	0.0401

From Table 2 and 3 it is obvious that even if lesser rise time and settling time is reported in ZNPID, it ended with massive overshoot which is not suggested. GA shows the best recital in terms of performance indices and time domain analysis compared with the controller ZNPID. Hence it is concluded that GA controller is best appropriate for the moisture process. Fig. 4 shows the curves of servo and regulatory tracking. Table 4 shows the robust specifications of $\pm$ 20%. A feature that is less frequently taken into concern is the capability to afford robust specification. The use of robust specification provides additional realistic recompense such as more controllable proof systems or more proficient automatic authentication algorithms.

VI. CONCLUSION

Investigational cram on humidification and control of equivalent were prepared in laboratory extent. For the Moisture process, First Order plus Dead Time Process (FOPDT) was acknowledged by Sunderasan and Krishnaswamy (SK) method. For the attained Control Parameter, a tuning arrangement was fashioned. Tuning system is accomplished to interpolate and extrapolate the relation between control variable and the controller parameters over entire span of control variables. To end with, a detailed time-domain modeling of the Moisture Progression was performed. Then the ZN based PID (ZN-PID) controller and Genetic Algorithm (GA) based PID controller was implemented in MATLAB and was simulated to verify its recital. Thus GA based PID controller was able to produce a consistent response regardless of parametric variations with minimum overshoots and minimum settling time, and also by means of performance index. It is proven GA gives better performance than ZN-PID. Servo and Regulatory problem for the given moisture process was also recognized for both GA and ZN-PID. Robustness Specification was also identified for the given process. As a future work we would design this process for different controllers like Model Predictive Controller (MPC), Particle Swam Optimization (PSO) etc.

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