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Optimization of PID Controller Parameters for First Order plus Time Delay Process

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Abstract*: Pressure control could be a key process variable in industrial sector because pressure provides an important condition for air-conditioning, chemical reaction, boiling, extrusion, vacuuming, and distillation. Worse pressure control will cause critical quality, productivity and safety issues at the same time excessive pressure within a closed container will result in dangerous explosion. Hence, it is highly important to maintain the pressure at desirable range even in the presence of disturbance and the change in set point. Usually the pressure is controlled by Proportional Integral Derivative (PID) controller in industries because of its higher performance and simple structure over other controllers. The PID controller was designed using Z-N tuning method. Further the PID values were optimized for higher performance by using Pattern Search and Genetic Algorithm. Finally, the response of optimized PID controller was compared with standard Z-N PID controller. The error performance criteria like ISE, IAE, and IATE were used for comparison.

Keywords* : Genetic Algorithm (GA), Proportional Integral Derivative (PID), Pattern Search (PS) Algorithm, Integral Absolute Error (IAE), Integral Time Absolute Error (ITAE), Integral Square Error (ISE), Ziegler Nichols (Z-N).

I. INTRODUCTION

The measurement and controlling of pressure is a considerable importance in process industries, and it was controlled by PID controllers with good response produced by tuning methods like Z-N, Cohen-coon was used. Here approached the PID values with the optimization techniques for better performance than the tuning methods. The optimization methods, used are genetic algorithm and pattern search algorithm, the genetic algorithm is examining algorithms imitates the ideologies of biotic advancement, such as reproduction, selection and genetic recombination.

Examples from the works contain the request of replica tactics created on people heredities to active structures device and factor optimization [1]. Genetic algorithmic program useful in PID organizer advances FOLPD transitory reaction related to dual calibration ways. This is presented via normal percent overshoot fall, further than 80% and 20% with approval to Iterative Method and Z-N rule whereas observance the peak time (T_p) and rise time (T_r) almost not affected and advances the settling time (Ts). Yet, there's pay-out within the strength margin that lesser marginally related to dual calibration ways [2]. Genetic Algorithm centered PID controller fine-tuning is planned and realistic to the (CSTR) procedure. Since the simulation lessons, tend to conclude that enhanced organizer factors attained by executing the algorithmic program with a slanted arrangement of IAE, ITAE and ISE as value catalogues have realized adequate set point pursuing and trouble denial in the whole functioning range of the CSTR process [3]. The common principles of GA show indices, evidently, are always lesser than its consistent iterative and Z-N technique. Nonetheless, there is a difference between GA method and dual tuning methods, except for ITAE objective function where the distinguishing high as the time delay high is not sufficiently desirable to conclude that GA method is much larger than dual other methods in reducing error criteria [4].

Provide an optimized PS methodology for non-linear reserved division of PMUs in delicate means of transport through the provision of importance to qualify a better at redundancy at each bus with full system observation capability. By acting load flows at high loads, through which sensitive buses are recognized, propose a new VSI. The proposed PSA solution with the modeling of ZI Bus constraints and without the modeling of ZI bus constraints is related to proving process performance. A shot to crossbred flower crosspollination algorithm and PS algorithm has been rendered by learning this paper for the first time. The software estimated algorithm has the advantage of worldwide FPA quest and native PS technique search. Output slippery mode management feedback (OFSMC) is intended for multi-source, automatic generation control (AGC) framework. OFSMC's optimum parameters are improved with a cross-flower fertilization algorithm and PS (HFPA-PS) for unlike power transactions [6]. Hybridization of the FPA and PS algorithm for OFSMC optimization and contrary to traditional controller parameters, dynamic system output is contrasted with FOA and PSO optimized unlike conventional controllers [7]. The self-organizing approach for optimizing GA is used to build PID controller factors to evade early merging and to attain noble presentation in optimization [8].

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The paper is discussed in the below manner: Section 2 deliberates the pressure station model. Section 3 deals with Pattern Search. Section 4 discusses the Genetic Algorithm. Section 5 shows the simulated outcomes of ZN-PID, PS-PID & GA-PID and compared using the performance evaluation. Finally, Section 6 completes how the GA-PID is outperformed ZN-PID & PS-PID.

II. SYSTEM IDENTIFICATION

System identification could be a method for constructing dynamic system mathematical models using output and input signals of the system dimensions. The device identification process involves time or frequency field computation of the input and output signals from our network. Choose a prototype structure. Apply a valuation methodology within the candidate model framework to determine interest for the adaptable constraints. Appraise the calculable model to analyze whether the model is appropriate to your submission.

For that open loop test has been conducted in pressure process and the figure 1 shows the obtained a graph. From the obtained graph substituted the values to the mathematical equation for finding the transfer function.

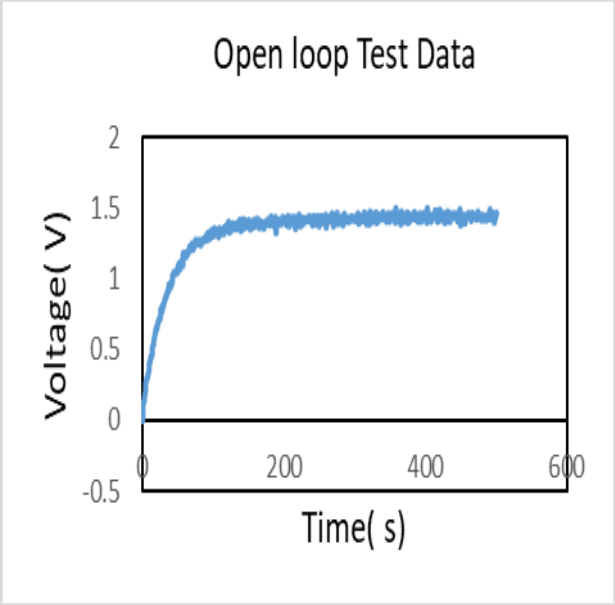

Fig. 1. Response graph of open loop test.

A. Process Gain (K_p):

It is a comparative rate that shows the bond between the magnitudes of the input to the magnitude of the output signal at steady state.

$$K_p = \Delta PV/\Delta CO \quad (1)$$

B. Process Time constant (τ_p):

It defines the speed with which the evaluated process variable (PV) responds to variations in the controller output (CO). A lot more specifically it embodies the time required for the PV to prosper in 63.2% of its total and ending alteration.

$$\tau_p = 0.63 * K_p \quad (2)$$

C. Process Time Delay (θ_p):

It is conveyed as period swing in the feedback variable u (t). It is a delay, when a controlled output (CO) signal is delivered up to the obtained processed variable (PV) when starts to acts.

III. PATTERN SEARCH

Direct (Pattern) search may be a technique for resolution optimization issues that doesn't need any data regarding the rise of the objective function. As critical additional old-fashioned optimization strategies that practice data regarding the slope or higher derivatives to go looking for an optimum purpose, an instantaneous search algorithm program hunts a collection of purposes round the present point, trying to find one wherever the value of the unbiased function is under the value at the present purpose. The Figure 2 shows the pattern search algorithm for optimization technique.

A PS algorithm calculates a series of points which are getting closer and closer to the best point. The algorithmic software hunts for a set of points, known as mesh, around the present objective at every step— the aim determined at the algorithm program's preceding process. If the algorithm program finds a purpose at some extent of a degree within the mesh that advances the objective function at the present point, the fresh purpose develops the present purpose at successive steps of the algorithm. The algorithm program stops once any of the subsequent conditions occurs: The mesh size is a smaller amount than Mesh tolerance; range of the amount of the quantity of iterations achieved by the algorithm program influences the value of maximum iteration; the entire number of objective function assessments performed by the algorithm program reaches the value of maximum function assessments; the space concerning the purposes found at one in poll and also the point found at successive in poll is a smaller amount than X tolerance.

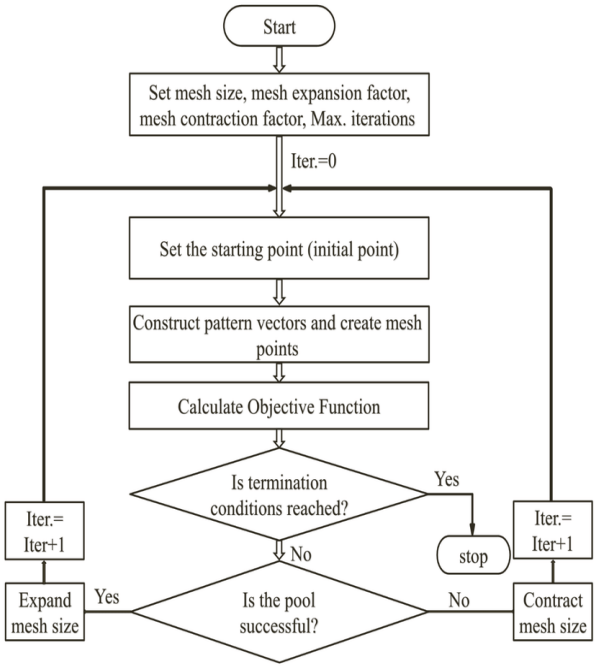

Fig. 2. Flowchart of Pattern Search Algorithm

A pattern could be an assembly of vectors that of the algorithm program practices to see that points to hunt at iteration. Meshes At every stage, the PS algorithm program hunts for a group of points, referred to as a mesh, to some extent that develops the unbiased function.

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The algorithm program formulates the mesh by increasing its arrangement paths by scalar, referred to as the mesh size. Adding the ensuing vectors to the present purpose — the purpose with the most effective objective function value create at the former step.The algorithm software scans the points inside the present mesh at each level by measuring their objective function values. When the default setting is set to the possibility of a whole poll, the algorithm program halts voting the mesh purposes as it currently is, because it discovers some degree whose unbiased function value is lesser than this stage. If this arises, the sample is known as efficient and thus function it discovers to make this purpose for successive iteration. Remember that the algorithm software measures only the weave points and their disconnected task values before it halts the survey. If the program of the algorithm flops to reach some degree to advance the objective function, the survey is called failed and therefore the present intent remains constant when iteration is efficient. If you set whole poll to on, the algorithm program calculates the objective functions values in any respect mesh points. The algorithmic program then relates the mesh purpose with the tiniest objective function value to this purpose. If that mesh purpose encompasses a lesser value than this purpose, the poll is effective.

IV. GENETIC ALGORITHM

The genetic algorithmic could be a technique for finding optimization issues that's depends on natural action, the method that drives organic progress. The GA program frequently alters a people at distinct resolutions. At each stage, the GA program picks units arbitrarily from this populace to be folks and acquires them to turn out the youngsters for following mutated groups. Over continuity of mutated groups, that group of people "evolves" toward a best resolution. You'll be able to apply the genetic algorithmic program to resolve a range of optimization issues that are not well matched for traditional optimization algorithms, together with issues during which the detached function perform is non-differentiable, extremely nonlinear, discontinuous or stochastic.

The GA program uses three key forms of rules at every stage to form future generation from this population:

1. Selection rules choose the people, referred to as oldsters that contribute to the population in future generations.
2. Crossover rules mix two oldsters to make kids for future generations.
3. Mutation rules spread on arbitrary changes to individual oldsters to make youngsters.

Normally this (mating pool) is expressed through a real-evaluated set of binary sequence called gene. The presentation of the specific is determined and evaluated by the objective function, which allocates an equivalent range to each person entitled to its fitness, these genetic codes is determined, and the most successful strategies for endurance are applied. During this attempt the error price is used to determine the quality of every genetic codes. There are triple key actions to a GA: replication, fusion and mutation. Figure 3 indicates the sequence of actions in the GA. The GA program uses the following five situations to figure out once and for all: generations The algorithm program halts once the quantity of groups determines the worth of groups; time limit, the algorithm program halts once and for all for an extended period of time in seconds up to time limit; fitness limit, the algorithm program stops once the sense of the aptitude performs for the shortest time limit. Stall generations — the program halts if there was no enhancement translation within the detached task for an order of sequential peers of length Stall generations; Stall limit — the program halts if there was no enhancement within the detached function throughout a break of your time in seconds up to Booth limit.

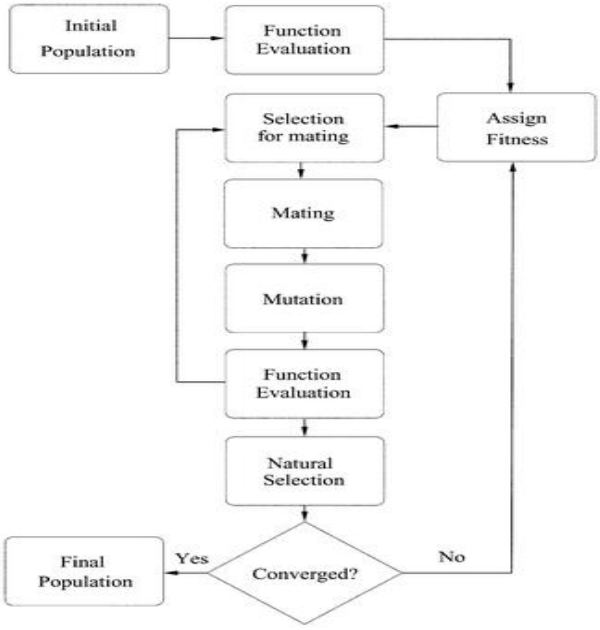

Fig. 3. Flowchart of Genetic Algorithm

Fitness is to assess the aptness of a genetic code. By the norm of endurance of the rightist, a genetic code with large aptness value contains a high chance of subsidizing one or a lot of progeny within the next peers. The aptness value of a particular is that the value of the fitness functions for that individual. As a result, it finds the least of the aptness function, the most effective fitness value for a populace is that the smallest aptness value for any person within the populace.

At every stage, the GA program uses this population to make the youngsters that frame future generations. The algorithm program chooses a bunch of people within the current population, referred to as folks, who donate their genes: the items of their vectors — to their youngsters. The algorithm program sometimes picks out people that have higher fitness values as folks. You'll be able to agree the function that the algorithm program uses to pick out the oldsters within the choice function arena within the choice options.

V. RESULTS AND DISCUSSION

A. Servo Response

The figure 4 shows the servo response of a pressure process station. For identifying the response of a system for servo problem, different set point is given as input to the system at different time.

The obtained response was evaluated using time domain specifications. The GA, PS and ZN tuning PID controller gives almost same rise. Then the peak overshoot for GA tuning PID was much lesser than PS and ZN PID. In-case for settling time parameter concern the GA has outperformed than PS and Z-N techniques.

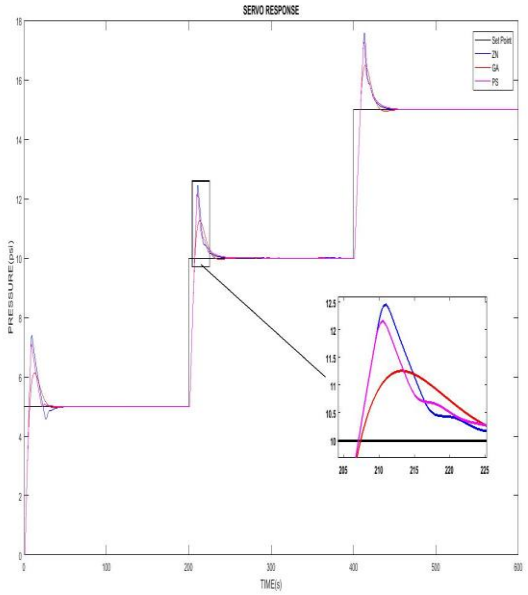

Fig. 4. Servo Response of a Pressure Process Station

B. Performance comparison of Servo Response

Table- II: Performance Comparison of Servo Response

Controller	ZN	PS	GA
IATE	53.77	53.19	50.26
IAE	25.1	23.63	22.33
ISE	13.01	12.14	11.22

The performance criteria like ITAE, ISE and IAE are given in the Table I for the ZN, GA and PS algorithm. The above comparison shows that GA gives minimum error than ZN and PS techniques.

C. Regulatory Response

The figure 5 shows the regulatory response of a pressure process station. For identifying the response of a system for regulatory problem, different set point is given as input to the system at two different times to overcome the disturbances. The response that obtained is evaluated with time domain specifications for finding the best PID controller. For the rise time and peak time parameter all three technique nonetheless give same response. Then in-case of peak overshoot and settling time parameter, the GA give satisfactory response and overcomes the disturbance better than PS and Z-N techniques.

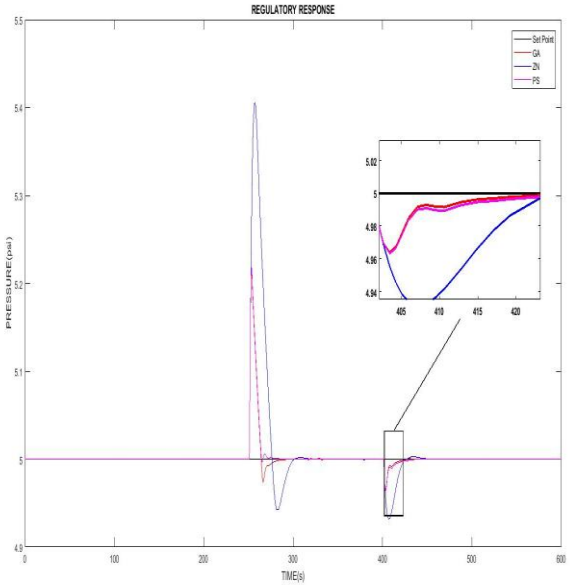

Fig. 5. Regulatory Response of a Pressure Process Station

D. Performance comparison of Regulatory Response

Table- II: Performance Comparison of Regulatory Response

Controller	ZN	PS	GA
IATE	327.5	118.4	151.6
IAE	8.614	7.861	7.27
ISE	4.155	3.75	3.364

The performance criteria like ITAE, ISE and IAE are given in the Table II for the ZN, GA and PS algorithm. The above comparison shows that GA gives minimum error than ZN and PS techniques.

VI. CONCLUSION

The pressure process station was taken for analysis. The open loop test was conducted by giving pressure as input and taking pressure as output. By using an open loop test data, the First Order plus Time Delay process model was identified. For achieving the required pressure for the system, optimized PID controllers were used. For optimizing the PID controller values PS and GA optimizing techniques were used. The deliberated optimized controllers were compared with the traditional ZN-PID controller. The errors like IAE, ITAE and ISE were used for analysis the performance of the controllers. By analyzing the simulated result, it is clear that the GA optimized controller give satisfactory response for both servo and regulatory problem than the PS optimized controller and ZN-PID controller.

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