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PERFORMANCE INDEX BASED COMPARATIVE ANALYSIS USING PSO AND GA FOR HIGHLY NONLINEAR COMPLEX CONTROL SYSTEM

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ABSTRACT
In the various industry application research on the multivariable process in nature. Control and interaction problem are major issues in the MIMO process. In the MIMO has a problem to develop a new controller very um manageable because of the interaction and process dynamics with a change of process parameters. For a simulation of the recommended method using nonlinear System. Quadruple Tank System is highly complex nonlinear systems which utilized in minimizing interaction and try to control and make stabilized the nonlinear system. The objective of the research work to design the optimized the performance index based PSO and GA implemented in Quadruple Tank System. The proposed system testing and simulation in MATLAB recourses. In this technique gives better disturbance attenuation with the good performance index result.

KEYWORDS: Nonlinear Quadruple Tank System, PSO, GA, Performance index.

INTRODUCTION
Nowadays increasing technological demands has the final result in a various complex process which to convert a high new development controller to the grantee that high quality and the best result is achieved and maintain under various changes in the parameter. There are specific requirement in control of a highly non linear complex system which conventional control cannot achieve desired performance for the various system area like, underwater vehicle, spacecraft, robotic, avionics, various chemical manufacture system which needs automatic operation and requests to help and are requirements to help for maintaining sufficient parameter level due to nonlinearity and equipment failure. For achieving the most effective degree of the performance, process system needs to have built in intelligence which is robust to change parameter variation or external and internal disturbance. Artificial intelligence is a technology that helps the intelligent controller to develop the compatibility of learning self- organizing online from the process response and the proper decision for control action to try for achieves desired performance. In the controller which has reasoning power, but it does not necessarily depend on the input to make a specific decision. In artificial intelligent control is mixing of a number of research areas like the fuzzy system, expert system machine learning, multi sensory fusion, failure diagnosis, control system theory, operation research, computer science, neural network. AI techniques that use various AI computing approaches like NN, PSO, Artificial Bee Colony, Genetic algorithms, bacteria forging various algorithms implemented for optimization of the controller parameter and assign into the class of intelligent control. This paper shows a design technique for the change the variable of PID controller and optimizers tune the PID constant using PSO and Genetic algorithms to improve the response of performance index. PSO and genetic algorithms implement the laboratory- based nonlinear system Quadruple Tank System (Quadruple tank System) MIMO system. To change the PID controller parameter on simulating in Matlab. Using the transfer function of the MIMO system of the QTS to minimize the value of the performance criteria. It will provide the controller with high disturbance rejection and minimize the various parameter related to the performance index (IATE, IAE)and reserved the robustness of Quadruple Tank System and minimize the effect of the interaction of the system. The ITAE is novel performance index used for complex nonlinear control system design. To

create High-quality result and result gives in shorter calculation time provided by the PSO technique and also gives stable convergence characteristic in [11]. The PSO techniques implemented to formulate the minimum PID control variables for application of automatic voltage regulator is suggested in [4].

PSO is good Optimization techniques for analysis of swarming principle has been assumed to solve a various nonlinear system problem in the last past decade. Swarm intelligence is a very attractive distributed intelligent techniques for solving an optimization problem that originally accepted its inhalation from the biological example in vertebrates. A population of particle presents in the number n dimensional look for place in which to optimize problem lives in the each and every particle has a specific value of cognition and will move about search based on the knowledge. The particle has specific inertia imputed to its and so it will keep on to have a component of move in the way is actuating [2].

Vrahatis and parsopoiles attempted to change to find efficiency in PSO by implementing two times transformations of the objective function which rejects and elevates the neighborhood of the local minima. The objective function is chosen so as to decrease the integral of time absolute error (ITAE) performance index. Comparative analysis between proposed (PSO and GA) tuning method and another method check and simulated in Matlab. After that result give in genetic algorithms better response compared to PSO based on the Performance Index.

II. MIMO QUADRUPLE TANK SYSTEM

The process which has nonlinear characteristics has a more interaction of quadruple tank processes, which are touchstone processes used in many industrial applications. This frame up is very simple and rugged but still, the system would elaborate concerning multiple variable techniques. The process flow diagram is viewed in Figure 1. The main object has to maintain to the levels Y1 and Y2 at bottom tanks with prime movers. This mathematical model needed for the present practical lab includes and also the disturbing effect of flows in and out of the upper-level tanks. Input voltage is applied to prime movers V1 and V2 (input voltages to the pumps). This process is represented by the differential equations according to the material balance equation [30].

Processes are represented by equations

$$\frac{dh_1}{dt} = -\frac{a_1}{s_1(h_1)}\sqrt{2g|h_1|} + \frac{a_3}{s_1(h_1)}\sqrt{2g|h_3|} + \frac{\gamma_1 k_1 v_1}{s_1(h_1)}$$

$$\frac{dh_2}{dt} = -\frac{a_2}{s_2(h_2)}\sqrt{2g|h_2|} + \frac{a_4}{s_2(h_2)}\sqrt{2g|h_4|} + \frac{\gamma_2 k_2 v_2}{s_2(h_2)}$$

$$\frac{dh_3}{dt} = -\frac{a_3}{s_3}\sqrt{2g|h_3|} + \frac{(1-\gamma_2)k_2 v_2}{s_3} - \frac{k_{d_1} d_1}{s_3}$$

$$\frac{dh_4}{dt} = -\frac{a_4}{s_4}\sqrt{2g|h_4|} + \frac{(1-\gamma_1)k_1 v_1}{s_4} - \frac{k_{d_2} d_2}{s_4}$$

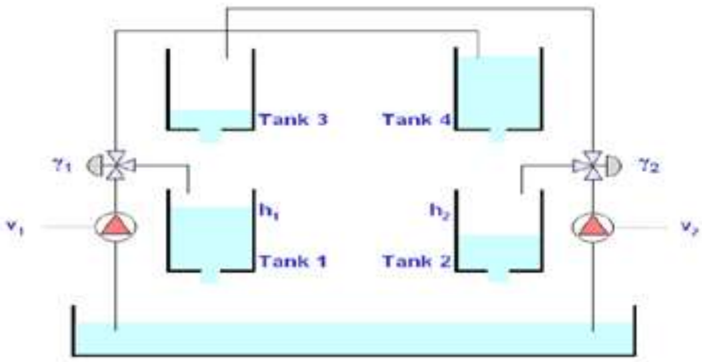

Figure 1: Experiment Quadruple Tank Process

This process presents interacting multiple variable dynamics, complex system because of each of the prime movers involves both of the outputs. This process exhibits nonlinear model and the nonlinear model converts to the linearized model of the quadruple-tank process has multi variable zero, which is to be situated on the left or

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the right half- s plane by adjusting the throttle valves position $\gamma 1$ and $\gamma 2$. It showed that the inverse response (non minimum phase) will happen when the value of this valve in the range of $0 < \gamma 1+ \gamma 2 < 1$ and minimum phase for $1 < \gamma$ $1+ \gamma 2 \leq 2$. The setting of the valve will be given to the overall system entirely dissimilar behavior from a multiple variable control point of view. Immeasurable disturbances can be enforced through forced water out of the main upper tanks and into the main bottom man made space small tank. It has been exhibited reject interference as well as mention covering the point. Using the multiple variable four tank process different aspects of multiple variable control systems can be illustrated. For example:

- Development and analysis of decoupling compensator.
- Development and analysis of state feedback compensator for different locations of the zeros.
- The valve settings effect on the location of the zeros.
- Recognize when a process is easy or not to control
- Design and evaluation of decentralized control.
- Development and analysis of mathematical model based predictive Strategy. Development and analysis of μ-analysis-based H∞ control.
- The locations of the zeros on the process output effect in different input directions

Controller Design

- The design method is compared with the various tuning method [10] of PID controller design approaches
- The Conventional PID controller method
- The Adaptive neuro fuzzy interference controller and
- The modified Adaptive neuro fuzzy interference (CANFIS) Controller
- Controller Tuning

The tuning of the controller could be explained as maintaining the variable of the controller so that the system dynamic response is better or response based on the designer. There are numerous performance criteria for controller tuning that may accept, some of which are considered

- Keep the maximum deviation as minimum as possible
- Decreases the integral of errors until the process has settled at its settling positions
- Gaining short settling times
- Performance Criteria

In the process control system, two types of performance criteria are to be satisfied, one is steady state performance criteria and second dynamic performance criteria. Performance criteria based on the closed loop response of the system are Overshoot, Rise time. Settling time, Decay ratio and frequency of oscillation. In the specified characteristics can be used by controller designers as per controller selection and parameter value adjustment. In the Design of controller mainly concentrates to minimize overshoot, minimum settling time and another parameter which related to having given system. If consider process is nonlinear, the main characteristics' will be changed from one operating point to another operating point after that specific parameter tuning can produce the desired response at the only single operating point in the system. If change operating point in the system change controller tuning. Adaptive controller and self-tuning controllers are design required fine tuning for a specific application. PSO and GA provide the best adjustment of controller parameters in the case of changing process dynamics.[30]

Tuning based on integral criteria

The response of the complete closed loop system at t= o until steady state has been achieved can be utilized for the formulation of the dynamic performance criteria. Based on the closed response, these methods minimized the area under error vs. time curve. Significant of the Tuning methods to minimize the integral of error so that towards address for minimum error integral. Minimize of Integral of error is not possible directly because a very large negative error will be minimum value, so that the absolute error value or square of error value is taken and decrease.

Integral of squared area: ISE = $\int e^2\, dt$

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Integral absolute error: IAE = $\int |e(t)|dt$

Integral of time multiplied by absolute value of error: ITAE = = $\int t|e(t)|dt$

For the computation purpose the upper limit of the integral may be replaced by settling time(ts)

III.PID WITH QUADRUPLE TANK SYSTEM

In the nonlinear quadruple tank system. This nonlinear system is utilized for implementing the modeling of single tank, two tanks interacting and non-interacting system. For single tank system flow measuring device Rotameter is utilized for measuring the input flow to the tank no 1. Input flow is given to the tank no 1 by maintaining the valve no 3 positions and the comparable level is measured with the help of standard calibrated scale along the length of tank1. The Level of liquid in the tank is also getting by the level transmitter in the range of specific current and voltage. In the Quadruple tank system, Two tank noninteracting systems Tank no 2 and Tank no 3 is utilized for implementing two tank non interacting systems by adopting the opening of valve no 2 at the desired fixed position. Input flow is indicated through flow measuring device Rotameter. Input flow is getting by adopting the opening of valve 4 and the corresponding level is measured by the need of calibrated scale along the length of bottom tank 2.The Level of the liquid tank is also indicated by the level transmitter, giving its output in the range of specifics of current and voltage. Two tanks interacting system Tank1 and tank2 is used to implement the two tank interacting systems by adjusting the opening of valve1 at the set position. Input flow is measured through roatameter1. Input flow is given by adjusting the opening of valve 3 and the corresponding level is measured with the help of calibrated scale along the length of tank2. The Level of the liquid tank is also indicated by the level transmitter, giving its output in the range of the particular value of current and voltage.

Simulation model of the Quadruple Tank System with PID controller

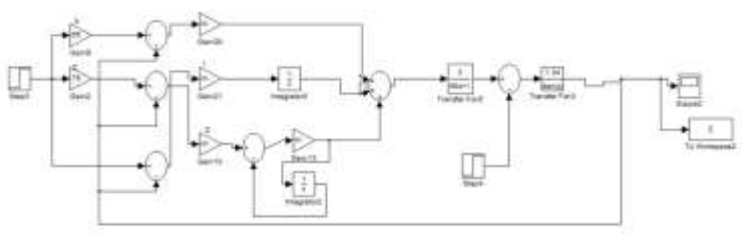

Figure: 2 QTS simulations in MATLAB.

IV. PARTICLE SWARM OPTIMIZATION

In computer science, PSO is a method that minimizes a trouble by iteratively trying to change problem results with reference to a specific measure of quality. It provides the effect a challenge have a population of problem solutions, this moves particles and traveling these particles near to the search-space based on primary mathematical rule over the particle's position and velocity. Each particle's drift is worked by its local well-cognized place but can also be run toward the well- cognized place into search-space, which is updated as best places are set up by some other particles. This is expected to move the swarm involve the better results. PSO is originally attributed to Kennedy, Eberhart, and Shi [1][2]and was first intended for simulating social behavior,[3] as a stylized representation of the movement of organisms in a bird flock or fish school. The algorithm was simplified and it was observed to be performing optimization. The book by Kennedy and Eberhart [4] describes many philosophical aspects of PSO and swarm intelligence. An extensive survey of PSO applications is made by Poli.[5][6] Recently, a comprehensive review of theoretical and experimental works on PSO has been published by Bonyadi and Michalewicz.[7]

PSO is really a metaheuristic so it produces very few or no judgment about the problem being minimized and can find very large places of prospect results. Even so, metaheuristics such as PSO do not ensure for minimum results is ever base. Also, PSO does not use the gradient of the problem being minimised, which means PSO not required that the minimised problem be differentiable as is needed by classic optimization methods such as one of the gradient descent and another quasi-newton methods

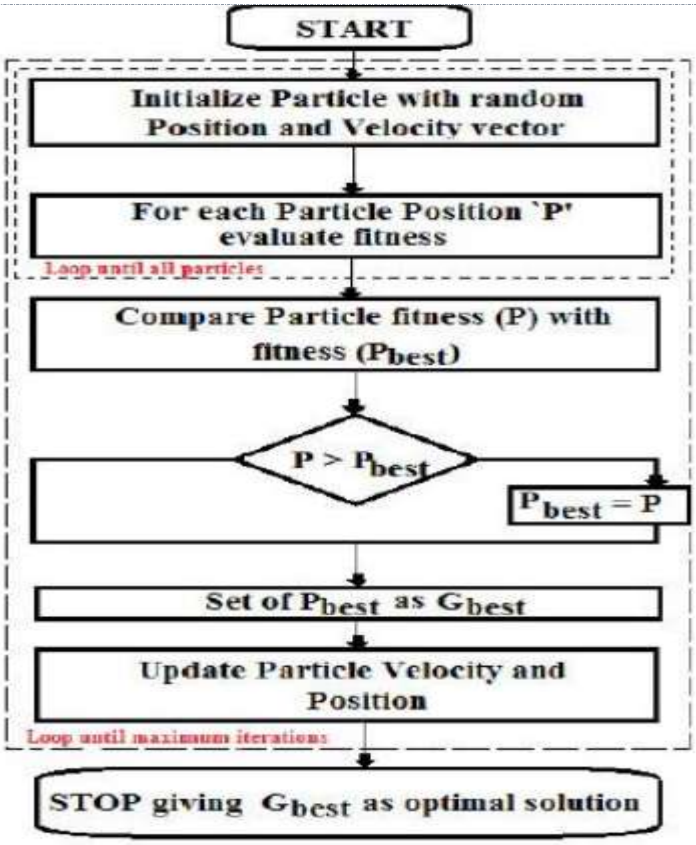

Figure 3 Flow chart on evaluation of PSO algorithm

PSO algorithm can be implied to the tune of PID controller variables to gerenttee optimal control performance at base operating conditions. PSO algorithm is applied to tuning PID variables using the two tank non-interacting liquid level model. Every particle considers member results for PID variables where their parameters are fixing in the span of 0 to 100. In this 3-dimensional problem, position and velocity are displayed by matrices with a dimension of 3 x swarm size. Parameters of PSO algorithm are considered. A good set up of PID controller variable selections can result a good system output and solution in minimization of the performance index.

TABLE: I PSO Specification parameter and their values

PSO Parameter	values
Swarm Size	100
Maximum iterations	70
Imax	0.9
Imin	0.6
C1	2
C2	4

V.GENETIC ALGORITHM

In Genetic algorithm is really a powerful search algorithm that executes through the examination of the finding place that develops in analogy to the evolution in nature. They choose probabilistic transition rules as controverter to deterministic principles and handle a population of potential solutions called individuals or chromosomes that evolve iteratively. Iteration of the program is termed as a generation. The development of solutions is imitated through a fitness function and genetic operators such as reproduction crossover and mutation. The fittest individual will hold out generation after generation, while also reproducing and generating offspring's that might be strengthened. At the similar time, the weakest individuals disappear from each generation. A GA is usually started with a population considering of between 20 100 individuals. This population mating pool is generally initiated by way of a real valued number or even a two-bit character called a

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chromosome. How well an individual performs a task is measured and assessed by the objective function. The objective function assigns each individual a corresponding number called its fitness. The fitness of each chromosome is assessed and a survival of the fittest strategy is applied. In this project, the magnitude of the error will be used to assess the fitness of each chromosome. There are three main operators for a genetic algorithm; these are known as reproduction, crossover, and mutation.

IMPLEMENTATION OF GENETIC ALGORITHM with QUADRUPLE TANK SYSTEM

The specific values of the conventional PID controller variables are found using GA. All possible set of controller variables is chromosomes whose rates are compensated so as to diminish the objective function, which in this event is the error criterion, which explains in detail. For the PID controller development, it is promised the controller settings approximated results in a stable closed loop system. Initialization of Parameters to start up with GA, certain parameters need to be defined. It consists the bit length of the chromosome, selection, crossover and, population size, mutation types, number of iterations, etc. These parameters selected based on a great extent the ability of designed controller. The range of the tuning

Parameters are considered in the range of 0-15.
Initializing the values of the parameters for this paper is as follows:
Population size – 300
Selection method – 'Maximum Geometric selection'
Crossover type – 'Single point crossover'
Crossover probability – 0.9
Mutation type –'Uniform mutation'
Mutation probability – 0.01
Bit length of the considered chromosome – 8
Number of Generations – 150

Objective Function for the Genetic Algorithm

The objective functions considered are based on the error criterion. A number of such specific touchstones are available and in this paper controller's performance is appraised in terms of Integral absolute error(IAE), Integral square error(ISE), Integral time absolute error (ITAE) performance error criteria. In this paper, its consider the restraint for the mathematical analysis for range or the given time, t=0 to t=ps, where ps is the settling time of the system to achieve steady state response for a constant step signal. Simulated response to find IAE, ISE, and ITAE.

Termination Criteria

Optimization algorithm can terminate when the maximum amount of iterations gets over or with the acquisition of expiration fitness value fitness value, in this case, is just reciprocal of the level of the main function since we consider for a minimize the value of the main function In this paper, the termination criteria are involved to be the attainment of considerable fitness value which occurs with the most quantity of iterations is 100. For each iteration, the best among the 100 particles considered as a potential solution is chosen. Therefore the best values for 100 iterations are sketched with respect to iterations.

VI. SIMULATION AND RESULT

Simulation result for optimized PID controller variable based on particle swarm optimization and GA Based PID controller for a given quadruple tank system involving various performance indexes ISE, IAE and ITAE and the combination of the different function is carried out for both rotaries as well as linear. In the simulation, highly nonlinear complex QTS process having mathematical modeling represent the in the MATLAB. In the simulation, perform mathematical model in Simulink with PID and PSO algorithm for tuning PID parameter and the GA algorithm for tuned PID parameters. The output of the system given the best result for GA in strand of PSO and conventional PID. In the Proposed tuned of PID controller based on GA utilizing ISE, IAE and ITAE separately. And the weighted combination of giving through function as objective function is able to nullify the disturbance and bring the level back to the desired position. simulation result proving satisfactory performance in all controllers. In the GA based controller gives the better performance index than others.

TABLE II Time Domain Specifications of Step Response

Operating Point		Parameter	PID	PSO-PID	GA- PID
Minimum Phase	Level 1	Settling time (ts)	245	90	95.98
		Peak Overshoot(%Mp)	2%	20%	9%
		Rise time (tr)	16	3	10
	Level 2	Settling time (ts)	150	10	12
		Peak Overshoot(%Mp)	14%	10%	12%
		Rise time (tr)	10	10	4
Non Minimum Phase	Level 1	Settling time (ts)	1500	146	13
		Peak Overshoot(%Mp)	15%	20%	8%
		Rise time (tr)	240	13	10
	Level 2	Settling time (ts)	1354	12.5	8.3
		Peak Overshoot(%Mp)	28%	15%	12.6%
		Rise time (tr)	200	6	4.5

TABLE III. Performance index Specifications of all controller

Performance Index /Controller	PID		PSO		GA	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
IAE	27	1.7	25	1.2	20	1.3
ISE	14.26	1.8	6.7	1.73	6.56	1.77
ITAE	20	24	17	22	25	21

VII. CONCLUSION

The various response of the system presented above prove the better in their performances of the GA tuned PID settings than the PID controller Z-N II tuned, PSO. The simulation responses for the system models validated reflect the effectiveness of the GA based controller in terms of time specifications. The performance index under the various error criteria for the tuned based on GA controller is always less than the other specified tuned controller. Above all the simulated responses confirms the robustness of the proposed GA based tuning for the nonlinear dynamic quadruple tank system. If the process conditions, changes, then the nonlinear system may become oscillatory and unstable. In order to overwhelm these disadvantages, advanced controllers and GA controller are implemented. The main advantage of the GA controller is, it provides a transparent framework for control system design and tuning Thus, GA is able to compensate for disturbances and model uncertainty.
The Nonlinear control system is studied and the mathematical model of nonlinear systems is developed. Conventional PID controller and PSO tuned PID controller implemented in the system and the results are tolerable. The performance of GA controller is found to be good which ignores the presence of any Nonlinearity in the system and comparative best result than Conventional PID and PSO.

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