TAGUCHI MPSO OPTIMIZATION TO IMPROVE PERFORMANCE INDEX FOR HIGHLY NONLINEAR SYSTEM WITH ANALYSIS AND VALIDATION

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Abstract

In many chemical and petrochemical processes plant having multiple input para and multiple output para for different processes. It is very difficult to control the highly nonlinear quadruple four tank system. It is always challenging due to the cross coupling effect of highly interacting system to stabilize and control of the mimo system. Still a very big issue for controlling nonlinear system research. Computer based nonlinear system for performance analysis and check validation of proposed TMPOS algorithm. The proposed laboratory set up to communication with MATLAB, LABVIEW and other controller platform. With the help of LABVIEW, implement and develop proposed algorithm and output of the proposed algorithm validate with quadruple four tank laboratory set-up for testing. The check the performance index based on the PID parameter tuning with proposed TMPSO algorithm and improve the response of different performance index for the experiment setup quadruple tank nonlinear system.

Index Terms: Quadruple Tank System, PID tuning, Taguchi MPSO algorithm, Performance Index.

I. 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

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.

For the reason that study, they did design on the reduce mandrel eccentricity and output tube bending positions of a billet inside multi-hole extrusion operation optimization. This research access produce the optimize responses with respect to the specific operation variable range on basis of the finding knowledge of the results through the very advanced procedure to again enhance the perfect solution of qualities. Hsiang and Lin analytical thought the gist of many operation parameters of the magnesium alloy tubes hot extrusion by using the statistical approach techniques and another analysis of variance (ANOVA) to improve the better result nature of other different parts. It's involved that temperature, the billet, in extrusion velocity, of heating and temperature of container affect the mechanical characteristics of extruded products. Diminish costly approximate trails and get the key forces of specific variables to make certain best quality [17]. Required best pairs of parameter values of a process by using PSO combine mutation mechanism (MPSO). PSO was assigned random velocity to each and considerable particle due to its search mechanism associates and its own. In this research work, quadruple tank system is laboratory-based highly nonlinear system standard model for an experimentation setup for research as well as practical aspect. Using Taguchi method find the optimized value for PID controller parameter after again this value optimized by MPSO algorithm so that more optimized result we are getting through Taguchi combine with MPSO.

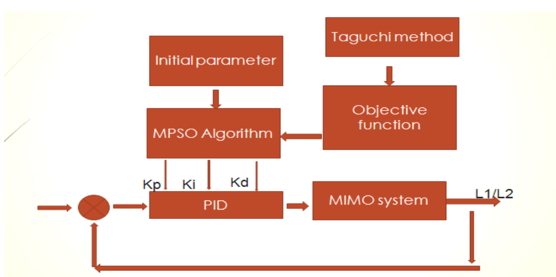

Fig 1: Block Diagram Taguchi based MPSO for MIMO System

II. QUADRUPLE FOUR 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.

Processes are represented by equations

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

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

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

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

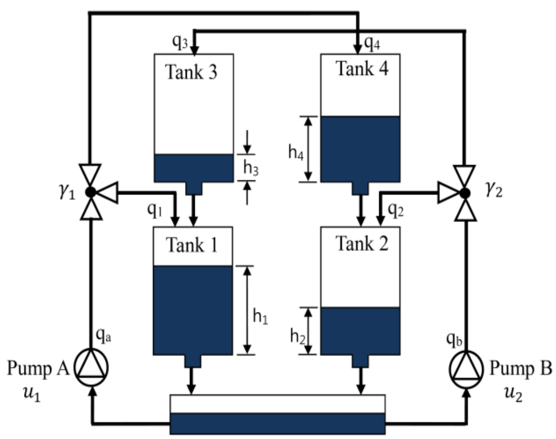

Fig 2: schematic diagram of Quadruple four Tank nonlinear system

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 the right half- s plane by adjusting the throttle valves position γ1 and γ2. 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 using different artificial intelligent approaches

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 is 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 Peak 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

Integral absolute error: IAE

Integral of time multiplied by absolute value of error: ITAE

Integral of time multiplied by Square value of error: ITSE

III. TAGUCHI METHOD (ANOVA)

The Taguchi method provides a very long meaning of explaining of the separate and mix results of different design principles based on the lowest number of trials (Al-Arifi et al., 2011) Taguchi approach for design variables is available in several categories as a result of an output of every variable to quality characteristics. The different levels of the process outcome are converts into s/n ratio. The standard ratio of signal to Signal to noise basically utilized are as follows: first is the Smaller value the Better, Second the Nominal value the Better, and third is the Higher value -The Better. This research study uses the ratio of Signal to Noise of the ISE, IAE, ITAE and ITSE performance to minimize the better stability of the nonlinear quadruple tank system process. The Signal to Noise ratio the Smaller-The Better (STB), characteristics is as follows (Lin and Chou, 2010):

$$\frac{S}{N} = -\log\left(\frac{1}{n}\sum y_i^2\right)$$

Where, n is the number of counts under the same design parameters, yi indicates the measured results and i presents the number of application based variables in the Taguchi OA. An output of S/N ratio figure of paramater levels indicates a better concept with preferable quality within the specified values. The ANOVA techniques utilized for in the Taguchi is a novel statistical approach first excepted to an analysis of the major values of application parameters and also the output of each variable, yi denoted the measured output results and i denotes the number of application parameters available with the Taguchi Orthogonal Array due to ratio of signal and noise, Effect of the Process parameter obtain based on ANOVA. The output of S/N ratio diagram of variable values shows a application with considerable prime within the specified value of variables.

IV. MUTATION COMBINED WITH PARTICLE SWARM OPTIMIZATION

The roots of PSO were instigated through the social behavior of fish schooling or bird flocking. Eberhart and Kennedy counseled the particle swarm computer program optimization pso methodology in 1995. In the search space indicates a good performance for each particle to the minimization specific task and representing as a bunch of different specific variables. This is linked with two path which name is the positioning and velocity path, which called name is the position and acceleration vectors In nth -dimensional search space, the two vectors associated with each particle i are Xi = (xi,1, xi,2, . ., xi,n) and Vi =(vi,1, vi,2, . . ., vi, n), respectively. Every particle changes the levels its result will depend on it is own good survey and the good swarm overall involvement to search it is good fitness level using iterative changing. Moving ahead this iteration process, the change of position and velocity of each and every particle are evaluated

as shown in the equation. The global best position and acceleration are change after each iteration value.
Equation suggests the updated design variables after mutation of each up to date particle from previous equation. The proposed algorithms were designed to continuous change parameter in specified equation for specific method up to reach termination states.

V. EXPERIMENT SET UP DETAIL

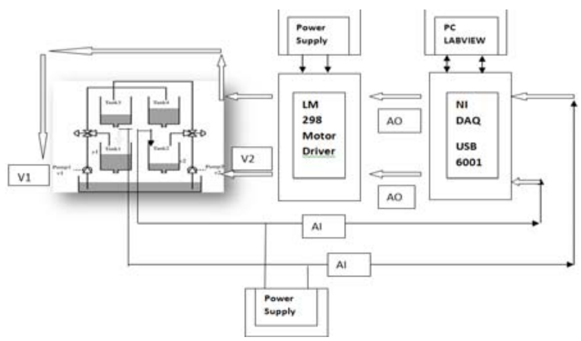

Fig 3 : Schematic diagram of Quadruple four tanks system

Fig 4 : Experiment Actual Quadruple four tanks system

In the quadruple four tanks system having two manipulated parameter as output of PWM signal to motor. The experiment laboratory setup involve of four tanks are interconnected in the process to control two parameter as level of the bottom tank1 and tank2. Fig: 1, seen the schematic diagram of nonlinear four tanks system. Output voltage is controlled through two pumps and two three way valves transport liquid in different manners. There are two three way valves which are used to decide the interaction between incoming and outgoing applied voltage to two pumps for controlling the flow of liquid. Level of the liquid is input of the system. Capacitive level transmitter is used for measurement of level. Due to effect of coupling disturb the bottom level of the liquid so that system going to unstable. Now figure 2 indicates experiment setup for implementing proposed algorithm. Laboratory setup consists of cost ion steel pipe structure to hold whole system elements plastic bottom as beakers, 1/8 “ piping, pumps having 24 volt DC 1.2 amp capacity and three way valves. Opening and closing of valves $\gamma 1$ and $\gamma 2$ spit the direction of liquid to bottom tank or upper tank and it is determine the interaction between two inputs and output of the nonlinear system. We used Capvel capacitive indicator cum transmitter for measurement of level. The output of transmitter calibrated level in terms of 1 to 5Vdc, its measurement span 15 to 3000pF, response time 0.5 to 5 sec. we does not necessary to use any signal conditioning circuit. Output of transmitter interfacing with NI USB based DAQ card directly and acquired signal in Lab view software user interface. NI DAQ card consist of 2 channels Analog Output, 4 channels Analog input, 8 channel Digital Input, 8 channel Digital Output. National instrument lab view software consists of PID tool kit to design and development of user interface with hardware and also implement tuning parameter real time for proposed algorithms.

VI. RESULT AND DISCUSSION

Fig 1 of the response of simulation and experiment setup of nonlinear quadruple four tanks system by implementing Taguchi MPSO PID tuning controller with Kp and Ki parameter of both controller. For step input consider as level (height of tank). In the multiple inputs multiple outputs system has worked with two different minimum and non minimum phase based on value of the three way valve position $\gamma 1$ and $\gamma 2$. The value of PID tuning by proposed algorithm. So controller tries to reduce the coupling effect between input and output. Response of the simulation and experiment setup given in table and also improve the response of performance index criteria ISE, IAE, ITAE and ITSE. The propose algorithm implemented with this setup.

TABLE I: Comparison Performance Index Taguchi based Simulation and Experiment data with MPSO for QTS (minimum phase)

Methods	Minimum phase ($\gamma 1=0.6$ and $\gamma 2=0.7$)							
	Level 1 (5 cm)				Level 2 (5cm)			
	ISE	IAE	ITS E	ITA E	ISE	IAE	ITS E	IT AE
Simulation Data	10.02	5.62	45.45	34.32	10.02	5.62	45.45	34.32
Experiment Data	18.09	10.66	90.45	52.29	19.09	10.03	90.45	51.29

TABLE II: Comparison Performance Index Taguchi based Simulation and Experiment data with MPSO for QTS (minimum phase)

Methods	Non Minimum phase ($\gamma 1=0.3$ and $\gamma 2=0.4$)							
	Level 1				Level 2			
	ISE	IAE	ITS E	ITA E	ISE	IAE	ITSE	ITA E
Simulation Data	10.02	7.62	50.45	30.32	10.02	6.62	47.45	33.32
Experiment Data	14.34	9.661	71.71	48.30	15.34	9.761	72.21	47.30

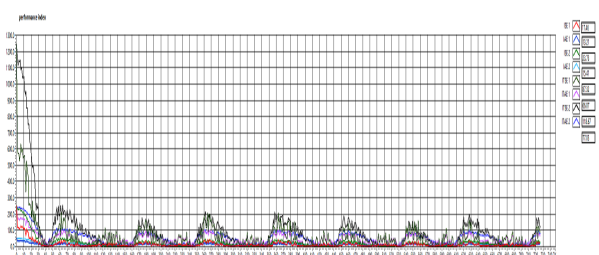

Fig : 5 Output responses of system Performance index for Experiment of Taguchi MPSO in Minimum phase

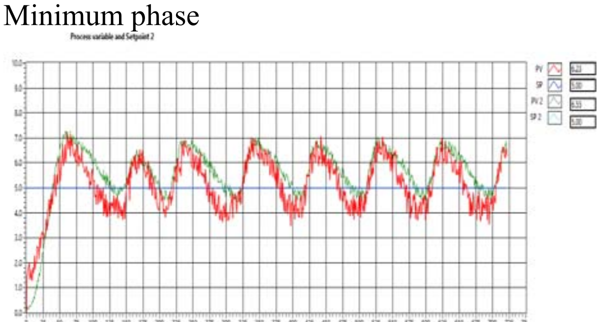

Fig : 6 Experiment output responses of system for Taguchi MPSO in Minimum phase

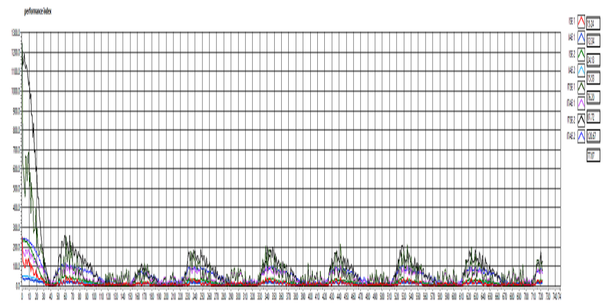

Fig : 7 Output responses of system Performance index for Experiment of Taguchi MPSO in Non Minimum phase

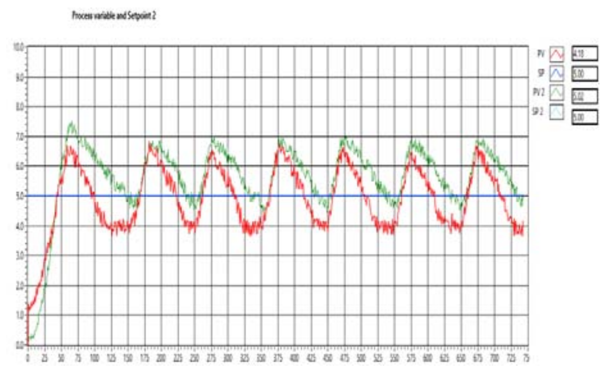

Fig : 8 Experiment output responses of system for Taguchi MPSO in Non Minimum phase

VII.CONCLUSION

Optimization based on Taguchi based MPSO algorithm for tuning of PID controller is developed using Lab view hardware and software experimental setup for analysis and validation purpose. This proposed algorithm implemented with laboratory setup to improve performance index as compared to other AI techniques. The performance of the system tested gives fine tuning parameter for said controller for different coupling effect along with multiple input outputs. The results compared with simulation and experiment setup time domain specification as well as performance index is improved. The proposed algorithm validate with quadruple four tank system.

This research paper presented for finding the best optimal solution for the nonlinear dynamic system. These techniques to find optimize the parameter of the controller for multiple inputs and multiple output dynamic system using Taguchi statistical method based on MPSO techniques. The effect indicate that taguchi based MPSO strategies can act as quality strategies of the MIMO nonlinear process and might be extended to different nonlinear method controller parameter for the industrial process control system.

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