International Journal of Research in Advent Technology, Vol.6, No.11, November 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

Design and Development of Complex Nonlinear System using TMPSO for Improving Performance Integral Criteria

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Abstract-.In many chemical and petrochemical processes plant having multiple inputs and multiple outputs for different processes. This research mainly focuses on searching the optimal controller structure by increasing the controllers' integral performance criteria. 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. It is still a very big issue for control of nonlinear system. The Proposed algorithm for tuning of PID constant based on the new statically approach combined with soft computing techniques. One of the optimization of statistical analysis Taguchi method is to combine with mutation based particle swarm optimization hybrid algorithm to tune the PID parameter. This tuning parameter optimized performance indices of the nonlinear system. The tuning parameters of controller find optimal performance indices. Design nonlinear based on lab view and NI Hardware nonlinear system for performance analysis and to check validation of proposed TMPSO algorithm. Laboratory experimental set up is established to communicate with MATLAB, Lab view and other advanced artificial intelligence controller platforms. Implementation is done using Lab view for proposed algorithm and output of validated with four tank laboratory set-up for testing. Check the performance indices based on the PID parameter tuning with proposed TMPSO algorithm.

Index Terms- Performance Indices, NI DAQ, Taguchi MPSO method

1. INTRODUCTION

As a result of increments of the worldwide competition and major changes in marketing and advertising business during the past many years, the process industry has presented a significant serious change in the market. Therefore it is essential to develop all the facet of process control technology such as modeling, dynamic optimization, integrated software tools, and high-performance process control. Process characteristics tend to become too complex to be successfully handled by the existing era of control and optimization techniques. One of the advanced control technology, which made a significant impact on industrial control engineering hybrid soft computing based control. The hybrid soft computing control technology is used to different soft computing algorithm meets all the performances to entice users. (Tyagunov, 2004). This is perhaps one of the most interesting and attractive approaches in process control practice for our century.

This Research work aims at combined developing the effect of PID controller parameter tuning based on improving the performance indices for the nonlinear control quadruple tanks systems in way of simulation as well as a real system controlled by the most used control laws in real industrial environments. Restriction of Conventional PID has been brought out by Lee and sung, even if the tuning of Z-N PID controllers. Integration method offers poor control performance in PID controller for and also considers the huge delay method[1]. Gimble and Ordys (2001) have presented a review of some will known predictive control algorithms like dynamic matrix control [2]. This marvelous technique will notice the sensible problem to improvement with finding issues. They concern to a specific category of biological Process programming that utilized techniques galvanized by a biological process like inheritance, mutation, selection and also a crossover. The best result is got by this algorithm giving a constant best fitness operate to attenuate. The genetic algorithm (GA) uses a direct analogy of such a natural evolution to do global optimization in order to solve highly complex problems (Goldberg, 1989). PSO algorithm is the most widely used optimization technique since it has fast convergence, few parameters to adjust and hence easy to implement. The interactions of the four tank system are studied and the controller strategies such as Internal model control, Bacterial forging optimization method and Particle swarm optimization techniques are implemented and analyzed using MATLAB Simulink to maintain the heights of the bottom two tanks. E. F. Ryckebusch, I. K. Craig presents the use of Taguchi methods for tuning PID parameters in a multivariable plant [3]. Anderson (2000) explains both the basic Taguchi procedure and how to use the analysis of variance for analyzing data. Awouda and Mamat (2010) found an efficient tuning method of the PID controller by using the optimization rule of ITAE performance criteria. The method implies an analytical calculation of the gain of the controller for PID controlled systems.

2. NONLINEAR SYSTEM

The highly nonlinear complex system is an example of a quadruple tank system that utilized to develop various control methodologies. The experiment process set up consists of four different interacting tanks, two manually operated valves, and two water transform DC pumps. It is said that multiple interaction double tanks process. First and second tanks are set underneath and third and fourth to get water stream due to the effect of gravity force. The two process inputs are the applied voltages v1 and v2 supplied thorough PWM signal to the two DC pumps. To mass the outgoing water from tank1 and tank2 a supply is available in the base every tank has a valve fitted to its outlet. The activity of pump 1 and 2 is to suck water from the supply and pass it to tanks based on the valve opening Pump 1 passes water to tank 2 and tank 3 and the pump 2 passes water to tank1 and tank4. Lower tanks get water from their related upper tanks due to gravitational effect. Purpose of the system is to maintain the liquid heights of the bottom tanks. The fluid levels in the lower tanks id controller we can say that the height of both tanks such as h1 and h2. These valve positions give the proportion in which the output from the water pump is separated between the upper position and lower position tanks. The water flow to the tanks can be balanced through the position of the valve. The position of the valve is settled amid the examination and just the pump if differed by changing the input applied voltage. The task of quadruple tank system can be grasped in two stages' to be a minimum phase and non- minimum phase. Consequently, the process can be kept in a minimum or non-minimum phase condition.

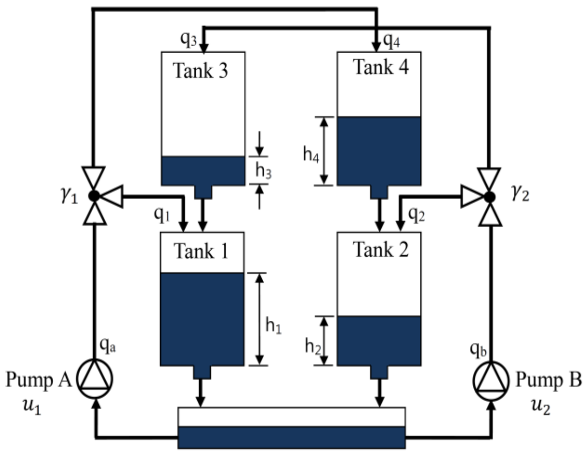

Figure: 1 Quadruple Tank System

2.1 Mathematical Modeling QTS

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. Process modeling is very essential to look into how the characteristics of a process response with time under the effect of changes in the extraneous interferences and manipulated variables and to consequently design a specifically selected controller. In this process have been used two different techniques, one of this is experimental setup and another one is a theoretical aspect. In such a case, a representation of the process is required in order to examine its process static and dynamic characteristics. These approaches are usually contributing in terms of a set of combination theoretical with mathematical equations whose solution gives the better dynamic characteristics of the process. The primary guideline mathematical model for this process utilizing mass balance, energy balance and Bernoulli s law is gotten. The process flow diagram is viewed in Figure1.1 the main object has to maintain to the levels γ1 and γ2 at bottom tanks with prime movers. This mathematical model required for the present experimental lab incorporates and furthermore the exasperating impact of flows in and out of the upper side-level tank. Input voltage is applied to prime movers V1 and V2. This process is represented by the differential equations according to the material balance equation. Processes are represented by equations

TABLE 1 : Physical parameters of the Quadruple-Tank

Parameter	Limit	Description
hi	Cm	Height of the tank i
Ki	Cm3/S.V	Voltage to volumetric pump constant of pump i
Kc	V/cm	Water level to voltage proportionality constant of sensors
γ i	[.]	The fraction of water flow of the pump
ai	Cm^2	The cross-sectional area of water outlet hole of tank i
A	Cm^2	The cross-sectional area of the four tanks

$$\frac{dh1}{dt} = -\frac{a1}{A1}\sqrt{2gh1} + \frac{a3}{A1}\sqrt{2gh3} + \frac{\gamma 1K1V1}{A1} \quad [1]$$

$$\frac{dh2}{dt} = -\frac{a2}{A2}\sqrt{2gh2} + \frac{a4}{A2}\sqrt{2gh4} + \frac{\gamma 2K2V2}{A2} \quad [2]$$

$$\frac{dh3}{dt} = -\frac{a3}{A3}\sqrt{2gh3} + \frac{(1-\gamma 2)K2\,V2}{A3} \quad [3]$$

$$\frac{dh4}{dt} = -\frac{a4}{A4}\sqrt{2gh4} + \frac{(1-\gamma 2)k1\,v1}{A4} \quad [4]$$

In the process control system, two types 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 the 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.

3. 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): =-log 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.

4. 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.

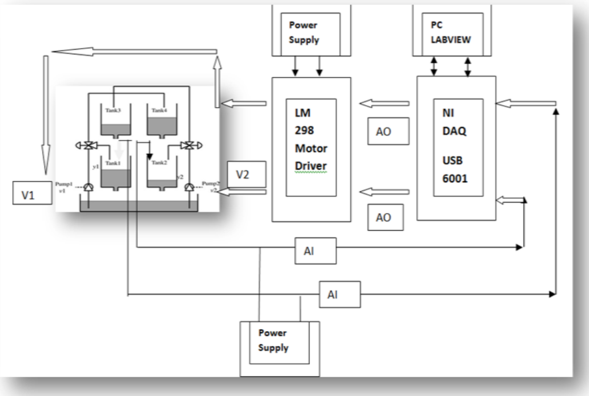

Figure: 2: Schematic Diagram of the Experimental Setup of QTS

Figure: 3: Real Experimental setup of QTS

5. RESULT AND DISCUSSION

The conceptualization of the 4-tank process as a multivariable control entity is originally proposed by (Johansson, 2000) and it is made up of four interconnected tanks in two pairs each, two pumps, two valves and two level sensors connected to the two lower tanks. Figures 1 is a schematic diagram of the experiment setup and Figure 3 is real experiment setup for quadruple tank system. Design and development hardware set up of the quadruple-tank nonlinear control system, for developing hybrid soft computing with statistical techniques based controller Lab view 17 used. NI DAQ 6001 is used for acquiring a level signal from the bottom tanks and to maintained the level of the bottom tanks which is maintained according to the generate analog PWM signal. to the motor drive circuit to produce from proper output voltage from DAQ and the motor running accord to level maintain control the level of both bottom tanks. We get the responses in two operating point; one is a minimum phase and second is a nonminimum phase. In the minimum phase response is better than the nonminimum. Performance of the system is check based on a performance index. Selection of the model performance based on the process data and process reveals system. Additionally, the performance index is used as a quantitative measure to depict the performance of the dynamic system. An optimal method may be differentiating using various techniques designed to match with the required parameter to the system. For a controlled system, we can use one of the four integral criteria to describe the system performance such as Integral Absolute Error (IAE), Integral Square Error (ISE), Integral Time Absolute Error (ITAE) and Integral time square Error (ITSE).

TABLE: 2 Comparative Analysis based on PID , PSO and GA Result

Parameter	**PID Z-N**	**PSO-PID**	**GA-PID**
Settling time (s)	300	255	247
Overshoot (%)	10.8	19	12
Rise time	275	234	222
Settling time(s)	320	266	254
Overshoot (%)	12.7	9	25
Rise time	275	234	222

TABLE: 3 Comparative Analysis based on Time Domain specification –Experiment Result

Parameter	**Taguchi PID**	**TGA PID**	**TMPSO -PID**
Settling time (s)	225	242	233
Overshoot (%)	11	10	9
Rise time	130	198	167
Settling time(s)	265	245	233
Overshoot (%)	21	13	8.5
Rise time	215	198	167

Table: 4 Comparative Analysis based on performance indices - Experimental result

Methods /Indices	**ISE (%)**		**IAE (%)**	
	L1	**L2**	**L1**	**L2**
TMPSO -PID	13.86	19.05	9.62	10.90
TGA -PID	13.97	20.49	9.51	11.09

Taguchi PID	14.79	20.18	9.83	11.01
GA PID	14.68	21.50	9.64	11.28
PSO PID	15.63	16.37	10.09	9.30
PID Z-N	18.13	24.32	11.03	12.30

Table: 5 Comparative Analysis based on performance indices - Experimental result

Methods /Indices	**ITSE (%)**		**ITAE (%)**	
	L1	**L2**	**L1**	**L2**
TMPSO -PID	69.3	95.25	48.10	54.50
TGA -PID	69.8	102.4	47.53	55.45
Taguchi PID	73.9	100.9	49.13	55.06
GA PID	73.3	107.5	48.19	56.41
PSO PID	78.1	81.88	50.45	46.47
PID Z-N	90.6	121.5	55.17	61.49

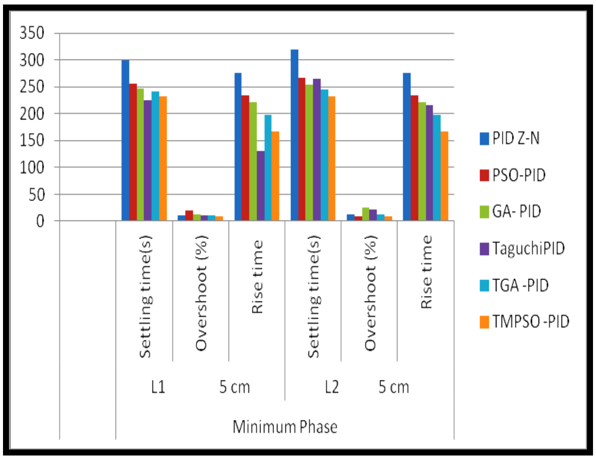

FIGURE: 3: Different techniques with Time domain specification Experimental result

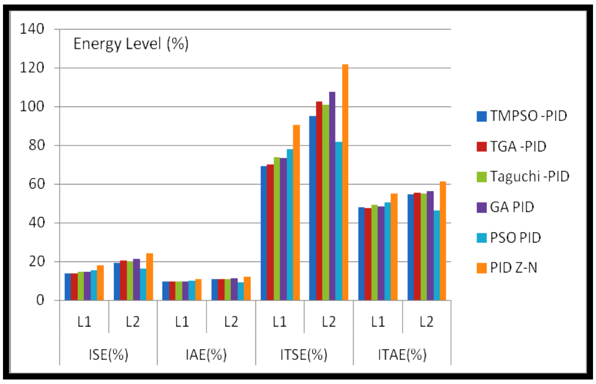

FIGURE: 4: Different techniques with Time domain specification Experimental result

6. 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 is implemented with laboratory setup to improve performance indices as compared to PID Z-N method, Genetic Algorithms, particle swarm optimization, with Taguchi techniques. The performance of the system tested gives fine tuning parameter for the 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 indices are improved. The proposed algorithm validates with the quadruple four-tank system.

This research work is carried out for finding the best optimal solution for the nonlinear dynamic system. This research found optimized the parameter of the controller for multiple inputs and multiple output dynamic system; using Taguchi statistical method based on MPSO techniques.

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