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Research Article

Genetic Algorithm Based Controllers Used In Multi Variable System

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Abstract

There are many systems in the world which are non- linear in feature. To regulate such processes, most enterprises relied solely on single loop control. In the process industries, multivariable device design is in high demand. The quadruple tank system is a multivariable, non-linear, and dynamic operation. The law of mass balance equations and energy equations apply to this method. Because of the interactions between the process variables, maintaining the tank level in a four-tank system is difficult. There are several traditional controls available for quadruple tank systems to regulate the tank's water level in the current process. However, not all controllers are suitable for implementation, and the performance accuracy during implementation is unreliable. As a result, in this papert, controllers such as Proportional Integral, Particle Swarm Optimization, and others are developed, simulated, and their output is compared using criterion such as settling time, peak overshoot, rise time and steady state error.

Keywords— PI controller, Tyreus-Luyben method, Ziegler Nicholas method, Auto –tuning, control.

INRODUCTION

A benchmark method for analyzing nonlinear effects in multivariable processes is the quadruple tank system.This aids in the implementation of multi-loop structures in industries.In multivariable control systems, the quadruple tank method is thus used to illustrate coupling effects and performance limitations. The way each pump affects all the system's outputs is the multivariable dynamic property of a quadruple tank system. The quadruple tank device is commonly usedinpower plant operations, chemical industries, and biotechnicalfields to visualize complexinteractions and non-linearities. MultiInput Multi Output (MIMO) devices are used in these applications.In the process industries, the regulation of such interacting multivariable processes is of great importance. Any device or process needs a controller. DAQ serves as a connection between the process station and the personal computer. [9][10]. The level of each tank is sent to the DAQ, which converts the analogue value into a digital value using an analogue to

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digital converter. The digital value is then senttoa personal computer, where it is compared, and then sentbackto the processing system via DAQ. The controller's output is provided to the process, which performs the specific activity. For real-time systems, there are a variety of controllers available. PI and PID, which are basic controllers, are the most extensively utilized. Other than basic controllers, genetic algorithmis used. Auto-tuning of PI controller relay in PMSM drives using delay and phase margin. A technique for auto- tuning a proportion plus integral (PI) controller for permanent magnet synchronous motor (PMSM) drives, which is intended to be included in an Electro-Mechanical A(EMA) control module in airplanes is presented by Wang Lina, Xiao Kun, Liliana de Lillo, Lee Empringham, and Pat Wheeler. The approach explores various crucial points in the frequency response of the system with a variable delay duration, a relay feedback is used. [6]. Naregalkar Akshay and D.Subbulekshmi this work FOPDT real time pH process used in online autotuning methods and auto tuning of PI Controller. The aimof thiswork is to create an method to establish the Transfer Function of a First Order Plus Dead Time (FOPDT) process usingtheProcess Reaction Curve identification method, auto selection oftuning methods using Ziegler- Nichols, Astrom HagglundandInternal Model Controller. [3] Rani Nooraeni, Muhamad Iqbal Arsa,NuckeWidowati Kusumo Projo describes the clustering is which is commonly used in data analysis using statistics in machine learning and data mining. Fuzzy based GA creates suggestions fordigits and grouping of qualitative mixed data. In real life, it used for information with both mixed attributes .Because of its usefulness in anaging a lot of content, the K-prototype technique was a very well clustering algorithmfor mixed data.

In practice, however, the k-prototype has two majorflaws using clustering center as a categorical attribute does not accurately reflect the objects, and the algorithmmay end at the local best remedy because it may be influenced by arbitrary network designs in their early stages. We prefer that our algorithmwil address the pitfall in k-prototype algorithm based on the outcome of the analysis.[17] Using an evolutionary genetic method, optimal receive beam forming in a spatial antenna diversity system is achieved. In wireless fading networks, Ridhima Mehta discusses the deep fading effects and wasteful resource utilization caused by un oriented information forwarding techniques, as wel asfrequent packet loss and power shortages. Diversity methods can be employed in wireless communication systems to mitigate the effects of fading and to increase the best service quality guarantees for data transmission. [18] A mixture of a genetic algorithm and a local search method was used to size a composite launch construction mechanically .Leila Gharsalli, Yannick Guérin explains that the goal of this work is to optimize a sandwich compositeinterstage skirt that is positioned in the upper section of a rocketstructure, a genetic algorithmwas used in conjunction with a localsearch approach. Local searches, unlike genetic algorithms, concentrate on a narrower subspace of solutionsdiscoveredby explanation they are efficient in the short termfor the genetic algorithmoptimization rather than the full universeofsolutions. [9][10]. A fuzzy system with determiner of a genetic algorithm.Amitkukker,Rajneesh Sharma the author demonstrates how reinforcement learning has been used to predict epileptic episodes.. For epileptic episodes, novelonline Genetic Algorithm aided Fuzzy Q-Learning and the use of fuzzy Q-Learning classifiers has been demonstrated. In the proposed Reinforcement Learning-based classifier's pre- processing stage, the Hilbert-Huang Transformis employedto extract 19 time-frequency domain properties.[18] The pattern of an exterior of a commercial building was optimized for energy savings using a quantum genetic algorithm. Chunyu Wei, Yuxing Wang Green architecture necessitates the development of building envelopelayoutswith cheap construction costs and low energy usage. Professional building optimization design software is now available.However, these systems take more time to

execute and desire additional feedback on build the foundation,making the design process difficult. Using specific optimization algorithms to improve building design is relatively straightforward. The genetic algorithmis a prominentapproach for optimizing architectural designs. On the other hand,genetic algorithms have the disadvantage of readily being stuckinlocal optimization. [22]
Parallel genetic algorithms are used to design embedded parallel systems.G.Talbi, T,Muntean Generic parallel genetic algorithms are built using the real-time path outlining problem for mobile robots as an example. The majority of robot motion planners are used off-line: theplanner is invoked with a model of the world, it generates a direction, and the robot controller executes it. In general, the time required to complete this loop is too long for the robot to travel around in a dynamic environment (moving obstacles). The aim is to reduce this period so that real-time route planning in complex environments can be handled.[23] A.Jayachitra and R.Vinodha suggest a PID (proportional integral derivative) controller based on agenetic algorithm(GA) for regulating a CSTRusing a consolidationof objective functions such as integral square error (ISE),integral absolute error (IAE), and integrated time absolute error(ITAE). The chemical and biological industries place a high value on optimizing PID controller parameters.PID tuning have shortened the operational range of systems with changing nonlinear behaviour. To get beyond the linear PID controller's limitations, we recommend running the CSTR mechanism across its whole operating range with globally optimized PID settings. According to simulation results,in the terms of set point observing and disturbance handling, a GA involvedPID tuned with settled PID specification provides adequate output.[15] The Genetic Algorithmhas been fine-tuned for the process.The major purpose of this study, accordingtoD.C. Meena and Ambrish Devanshu, is to apply Genetic Algorithm to construct a PID tuning methodology for a processing plant. The Genetic Algorithm, or GA for short, is a stochastic algorithm based on genetic principles and natural selection. GAs(Genetic Algorithms) are a probabilistic global search strategy based on evolution. [15]

Motivation

Nonlinear and multivariable systems make up thebulk of industrial processes. To achieve the desired overall control function, multivariable control problems are usually solvedby centralized PID controllers. Control device quality is determined by timing parameters such as settling time, rise time, and overshoot. The device provides good control efficiency if these parameters are kept small. This restrictstheir use in MIMO systems. This encourages one to createasuitable controller to resolve the MIMO system's controlchalengesand thus improve its performance.

EXISTING METHODOLOGY

PI Controller

A PI controller is a feedback linearization curve that monitors an error signal by minimizing the difference between a system's output and the set point, which in this case is the battery power drawn.. The output of the proportional integral controller is the sum of the outputs of the proportional and integral controllers. As a result, the proportional transfer function is KP+KIs.
The configuration of the PI controller is depictedinthe diagram above. It is made up of a PID block that process the block's outputs. Actuators, control valves, and other final control devices are used to control different processes in the industry/plant.

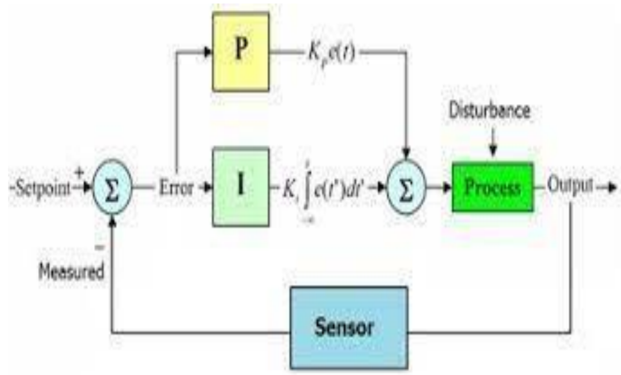

Fig 1. Block diagram of P+I Controller

PROPOSED METHODOLOGY

Auto tuning method

A self-tuning machine, according to control theory,is capable of optimizing its own internal running parameters in order to maximize or decrease the fulfilment of an objective function; generally, performance maximization or error minimization. The terms "self-tuning" and "auto-tuning" are also interchanged. Traditional tuning methods start with assumptions about the plant and the desired performance,then try to extract an empirical or graphical process functionthatcan be used later. These methods are simple to use and computein a short amount of time. These methods are fine at first, butdue to assumptions made, they do not always produce the desired results, necessitating further tuning.[30]

Tyreus luyben method

The Tyreus-Luyben technique is similar to the Ziegler–Nichols method in several ways, but the last controler settings are divergent. This method also only recommends PI and PID controller settings. The final gain and time settings are shown in Table 3. Internal Model Control (IMC) was proposed by Garcia and Morari, which is based on the Internal Model theory and incorporates the model of work and external signal dynamics. The IMC controller is a model-based techniquethat employs a work model and is renowned for its dependability. Robust, in mathematical terms, implies that the controllermust adhere to the specifications of a group of models rather than only one.Internal Model Control (IMC) is a model-based approach with a well-known process model for its reliability.. Robust, in mathematical terms, implies that the controllermust adhere to the specifications of a group of models rather than only one. In that it uses ultimate gain and ultimate time, this method is similar to Zeigler-Nichols, but the controller parameters are distinct.[30]

Table 1: Controller tuning parameters

CONTROLLER MODES	K_C	τ_I	τ_D
P+I	K_{CU}/ 3.2	2.2P_U	-
P+I+D	K_{CU}/3.2	2.2P_U	P_U/6.3

Ziegler-Nichols Method

The Ziegler-Nichols (ZN) method is a standardtuning technique that uses frequency response analysis to tune PID controller gains. This is the most popular way to tune a controller. ZN tuning methods are divided into two categories. The first is ZN tuning in an open loop, and the second is ZN tuning in a closed loop. The ultimate gain and length of the device are determined using the closed loop ZN tuning technique. Controller parameters are calculatedusingthevalues of ultimate parameters. It's a trial-and-error method based on the continuous oscillations of Zeigler and Nichols. The continuous cycling method is what it's known as. For this method, the quarter amplitude decay ratio is used as a design criterion. With a 14 decay ratio in mind, these controller settings were developed. Other environments, however,have been proposed that are close to critically damped control.[30]

Table 2: Calculation of Kp, Ki and Kd in Closed Loop

CONTROLLER	kp	TI	Td
PID	Ku/1.7	Pu /1.2	Pu/8
PI	Ku/2.2	Pu/2	-
P	Ku/2	-	-

The fact that we just need to change the P controllerjustifiesthe fact that it is easy to play with, and it also provides amuchmore informative scenario of how the systemis working by including all of the system's dynamics.

Genetic Algorithm

Genetic algorithmis used along with the PID controller to overcome the performance criteria.GA is familiar method of optimization which is being used to obtain the local optimum value. By adopting this strategy the error producedis verymuch less when contrast with the PID controller. In GA the bounds can be given to process with the iteration limits. GA optimization can solve many problems in variety of applications.

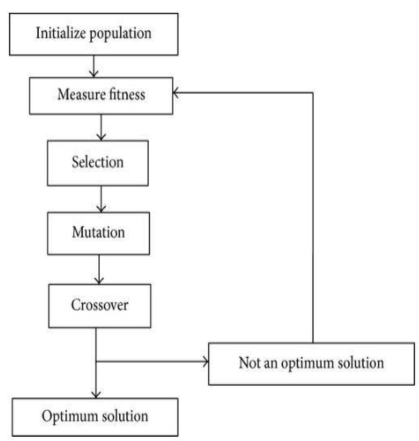

Fig 2. Block Diagram of Genetic Algorithm

The genetic algorithm uses the measurement set's coding rather than the variables themselves. The optimization can be used for value of changing, constant, linear, nonlinearandalso with noise.

RESULTS AND DISCUSSION

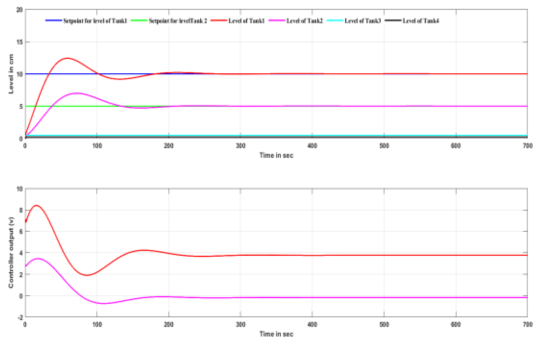

Fig 3 Minimum phase system by Auto Tune Method

Fig.3. shows the response of the Auto tuned PI Controller for Tank level 1 and Tank level 2 in Minimum phase

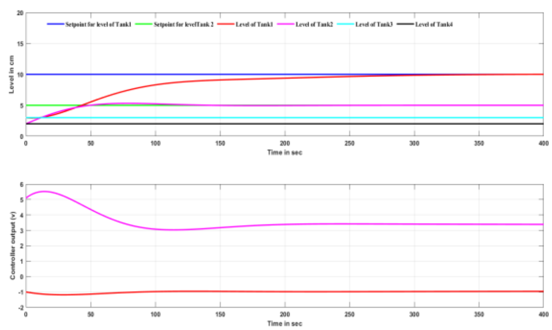

Fig 4 Non Minimum phase system by Auto Tune Method

Fig 4 shows the response of the Auto tuned PI Controlerfor Tank 1 and Tank level 2 in Non-Minimum phase

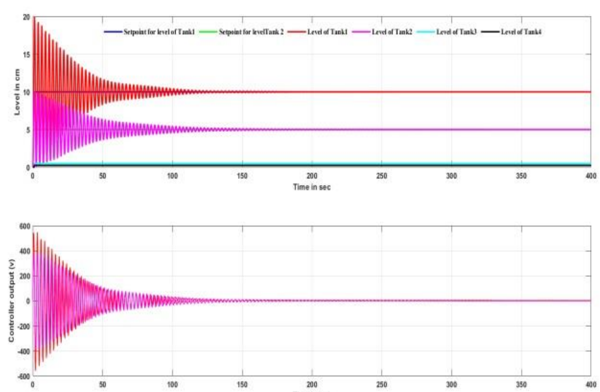

Fig 5 Minimum phase system by Tyre us Luber Method

Fig 5 shows the response of the Tyreus Luber method ofPI Controller for Tank 1 and Tank level 2 in Minimum phase

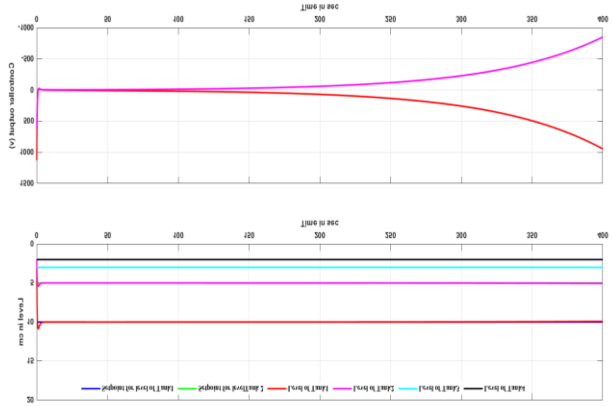

Fig 6 Non Minimum phase system by Tyre us Luber Method

Fig 6 shows the response of the Tyreus Luber method ofPI Controller for Tank 1 and Tank level 2 in Non Minimum phase.

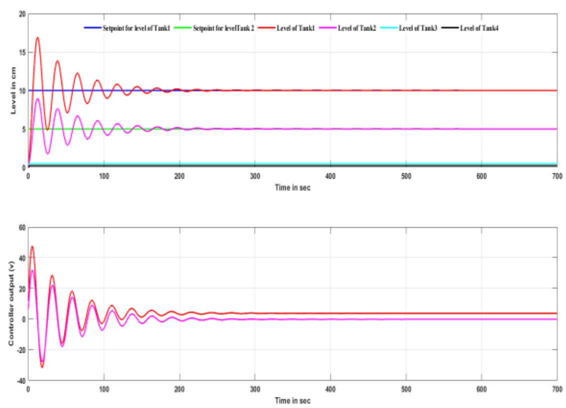

Fig 7 Minimum Phase System by Ziegler's Nichols Method

Fig 7 shows the response of the Ziegler's Nichols methodof PI Controller for Tank 1 and Tank level 2 in Minimumphase

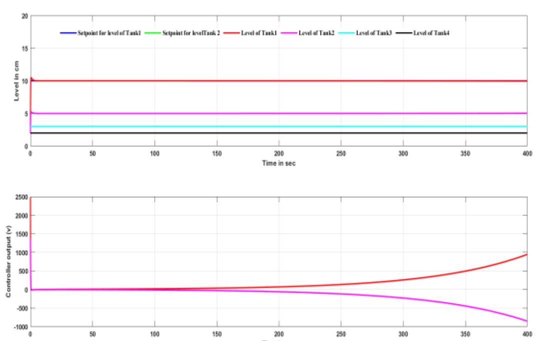

Fig 8 Non Minimum Phase System by Ziegler's Nichols Method

Fig 8 shows the response of the Ziegler's Nichols methodof PI Controller for Tank 1 and Tank level 2 in Non Minimum phase

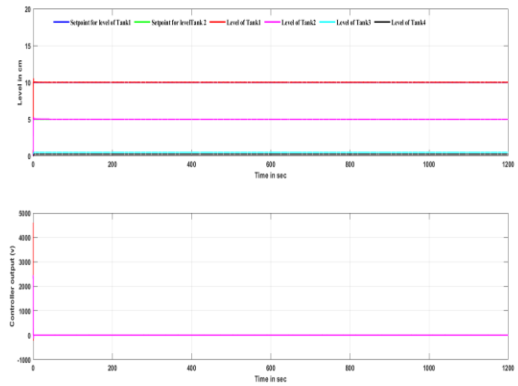
Setpoint for level of Tank1
Setpoint for levelTank 2
Level of Tank1
Level of Tank2
Level of Tank3
Level of Tank4
Level in cm
Time in sec
Controller output (v)
Time in sec

Fig 9 Minimum Phase System by Genetic Algorithm

Fig 9 shows the response of the Genetic Algorithm PI Controller for Tank 1 and Tank level 2 in Minimum phase

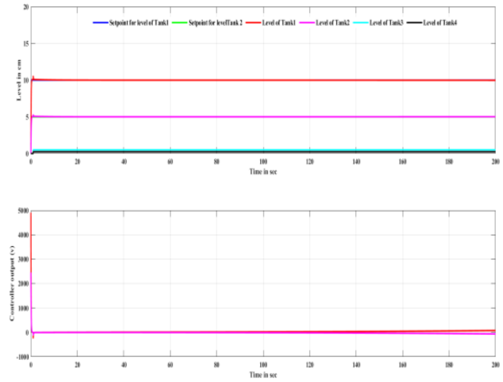

Fig 10 Non Minimum Phase System by Genetic Algorithm

Fig 10 shows the response of the Genetic Algorithm PI Controller for Tank 1 and Tank level 2 in Non Minimum phase

Table 3 Comparative analysis of different control methods

Non Minimum Phase System					
Tank 1	Rise Time	0.4	0.2	161	0.19
	Peak Time	1	0.6	400	1
	Over Shoot	10	5.2	0	6.09
	Settling Time	4	2.4	304	1.15
	ISE 1	7	3	2480	4.3
Tank 2	Rise Time	0.4	0.2	37	0.25
	Peak Time	1	0.6	79	1
	Over Shoot		4	6.2	6.07
	Settling Time	2.4	1.8	129	1.19
	ISE 2	1.3	0.6	116	1.5

CONCLUSION

Using device models and Luenberger controller architecture, the problemof state estimation for the Four-tank interacting systemwith MIMO configuration is investigatedin this paper. Initially, various types of models for the four-tank interacting systemare created using the systemidentification tool boxwith real-time plant data (process variables, time)and the models' output is compared and analyzed.MATLABisused to design and simulate particle swarmoptimization (PSO) inPI controller. The Genetic Algorithm dependent PI controller output forms the others when the controller parameters are compared. The settling time for GA-based PI is the shortest possible. As a result, in industrial applications, Genetic Algorithm is the best controller for quadruple tank systems. Among these methods from table 3, it is observed that the Genetic Algorithm method shows the best response where compared to the other tuned controllers

FUTURE SCOPE

In future, plant models can be used for designing various type controllers for four tank interacting systemwith single input single output configuration. Implementation of Sliding Mode Control (SMC) for Quadruple Tank System.

Tank	Parameters	Tyreus Luber	Ziegler Nichols	Auto Tune	Genetic Algorithm
	Minimum Phase System				
Tank 1	Rise Time	0.43	5	27	
	Peak Time	1.2	12	59	
	Over Shoot	100	69	24	
	Settling Time	114	186	171	
	ISE 1	912	964	1162	
	Rise Time	0.4	5	31	
	Peak Time	1.2	12	71	
	Over	102	78	40	

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